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45th Annual Fuze Conference
16-18 April 2001
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Wednesday, April 18, 2001

SESSION IV-A

SESSION V-A

Low Cost, Shock Hardened Recorder

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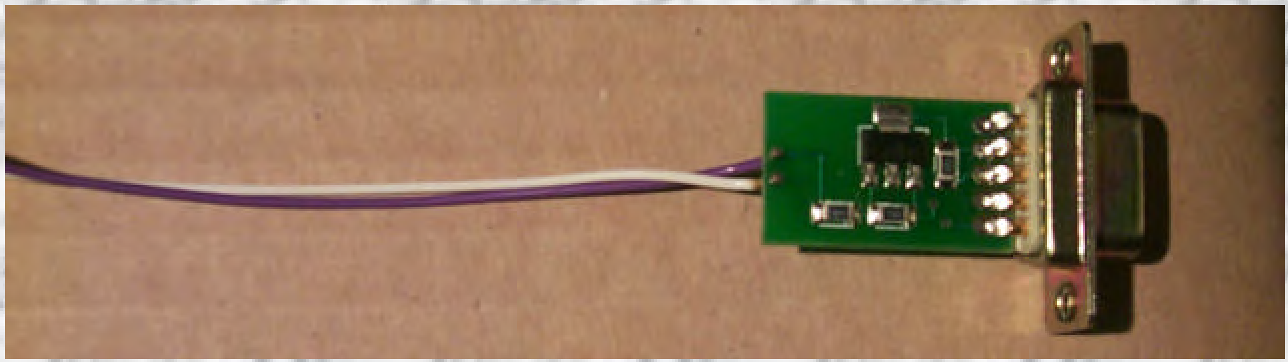
760-939-7775

Overview

- Low cost data recorder with non-volatile memory, capable of operation through high shock environments
- User configurable input modes
- Simple serial data interface for downloading stored data



Features & Benefits

- Non-Volatile Memory
  - 100 Year Data Retention Over Industrial Temperature Range (-55 to +150 storage, -40 to +85 operational)
  - Auto Recall During Power Up
  - Auto Store During Power Down
  - SRAM and EEPROM
  - 16 x 32k data storage

Features & Benefits

- Configurable
  - Single 16-bit Analog Channel
  - Single 12-bit Analog Channel and 4 Digital Channels
  - Single 8-bit Analog Channel and 8 Digital Channels
  - Jumper Selectable Sample Rate

Features & Benefits

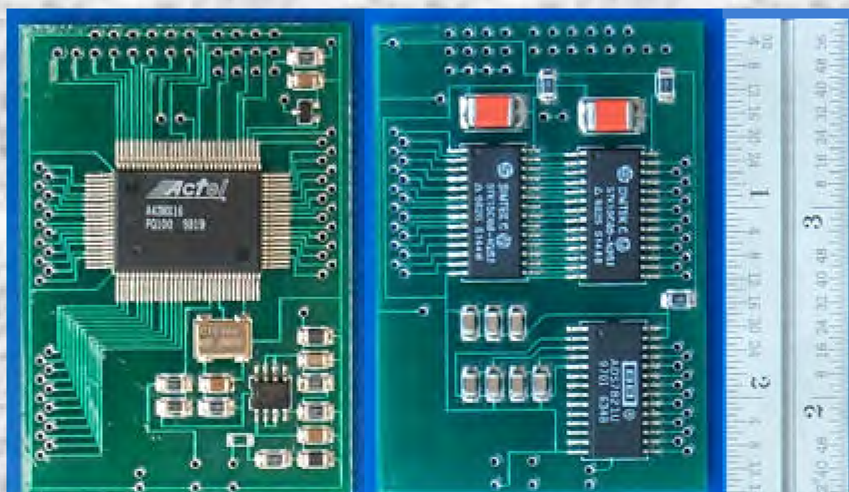
- Easy to use 5-Wire Interface
  - RS-232 Serial Connection for Download
  - Wide Input Supply Voltage (7 to 35 Volts)
  - Single Wire for Trigger/Mode Input
  - Data Stored in Spreadsheet Format by Reader Software

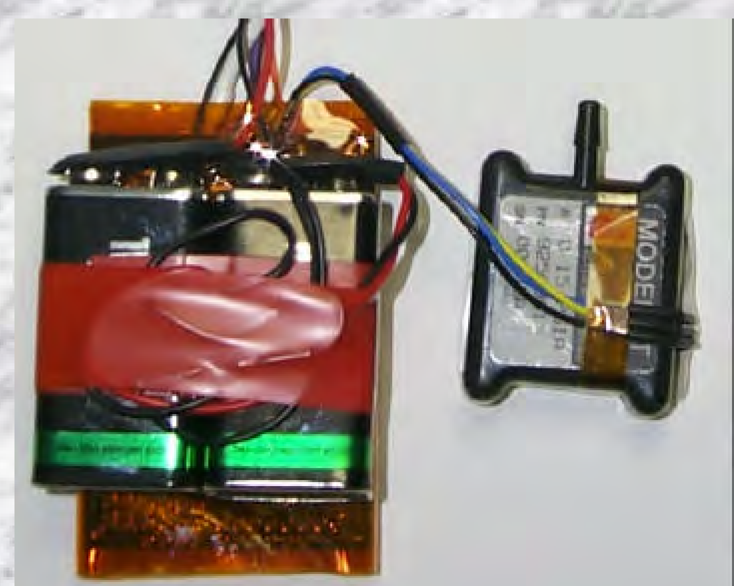
Features & Benefits

- Alternative Configurations
  - Expanded Memory Version (4x)
  - Low Voltage Version (2 to 9 Volts)
  - On-Board Signal Conditioning Version
    - Differential Input
    - Programmable Gain Stage
    - Low Pass Filter (fc = 1/10 Sample Rate)
  - Serial Data Capture Version

Applications

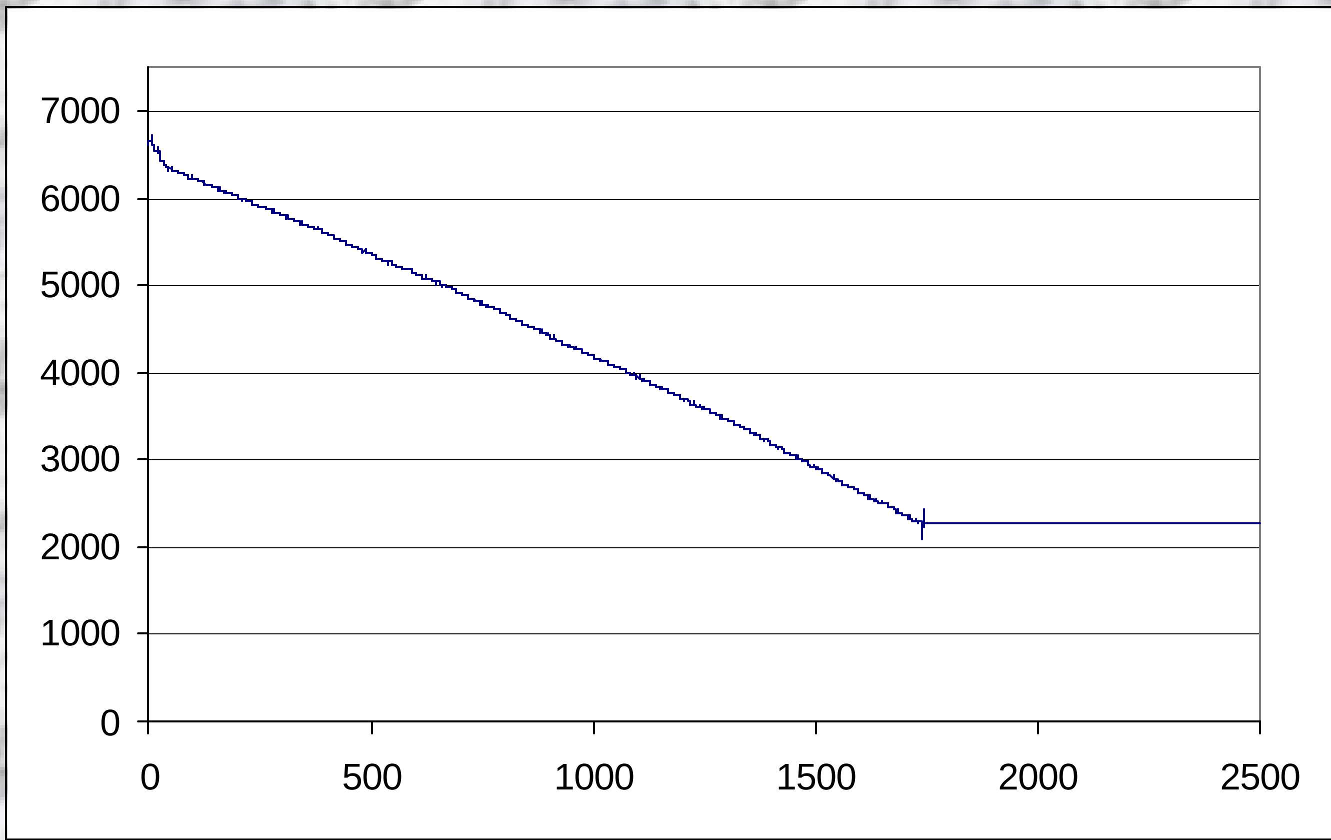
- Parachute Drop Testing
  - Low Cost
  - Compact and Light Weight
  - Simple





Applications

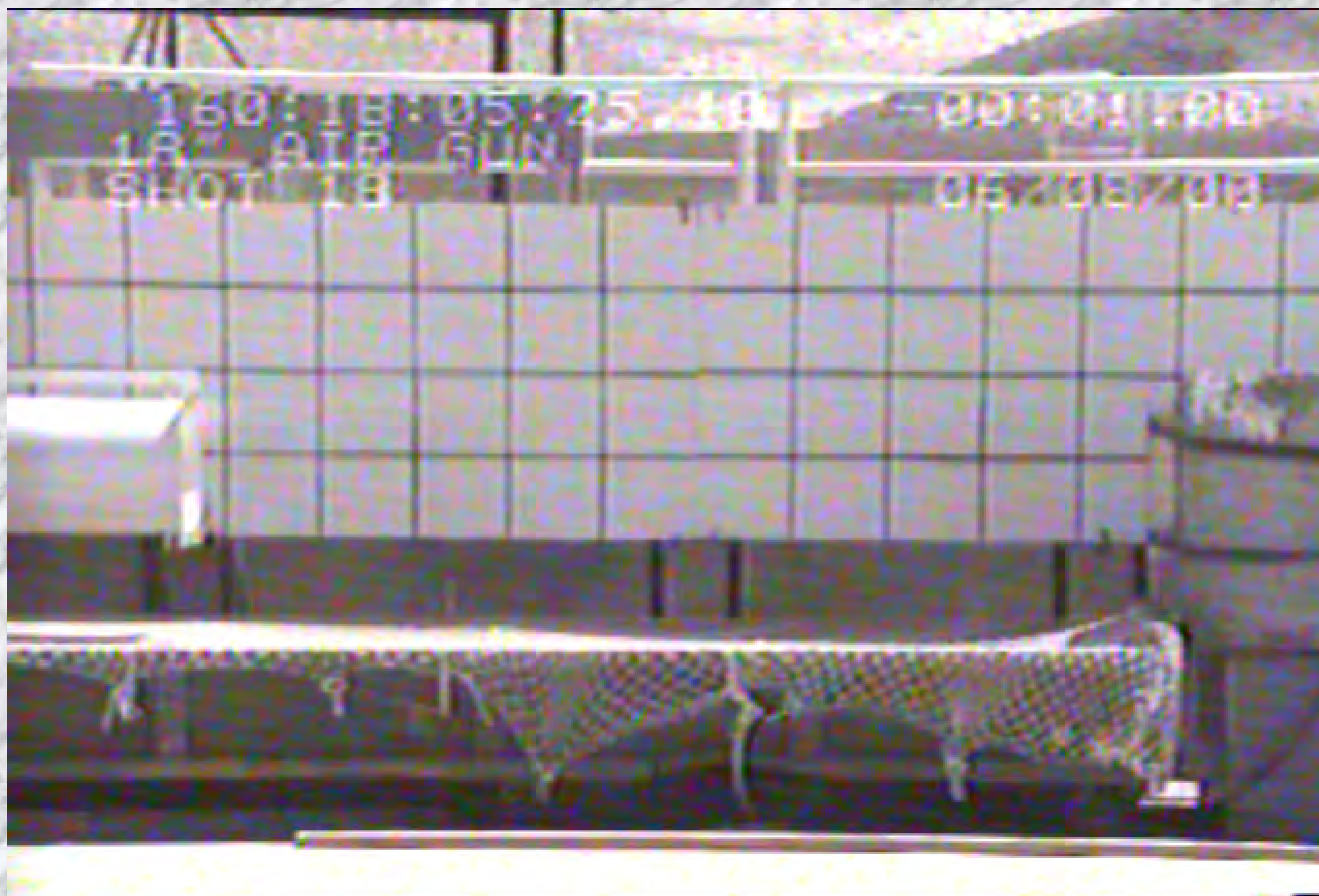
- Drop Test Data



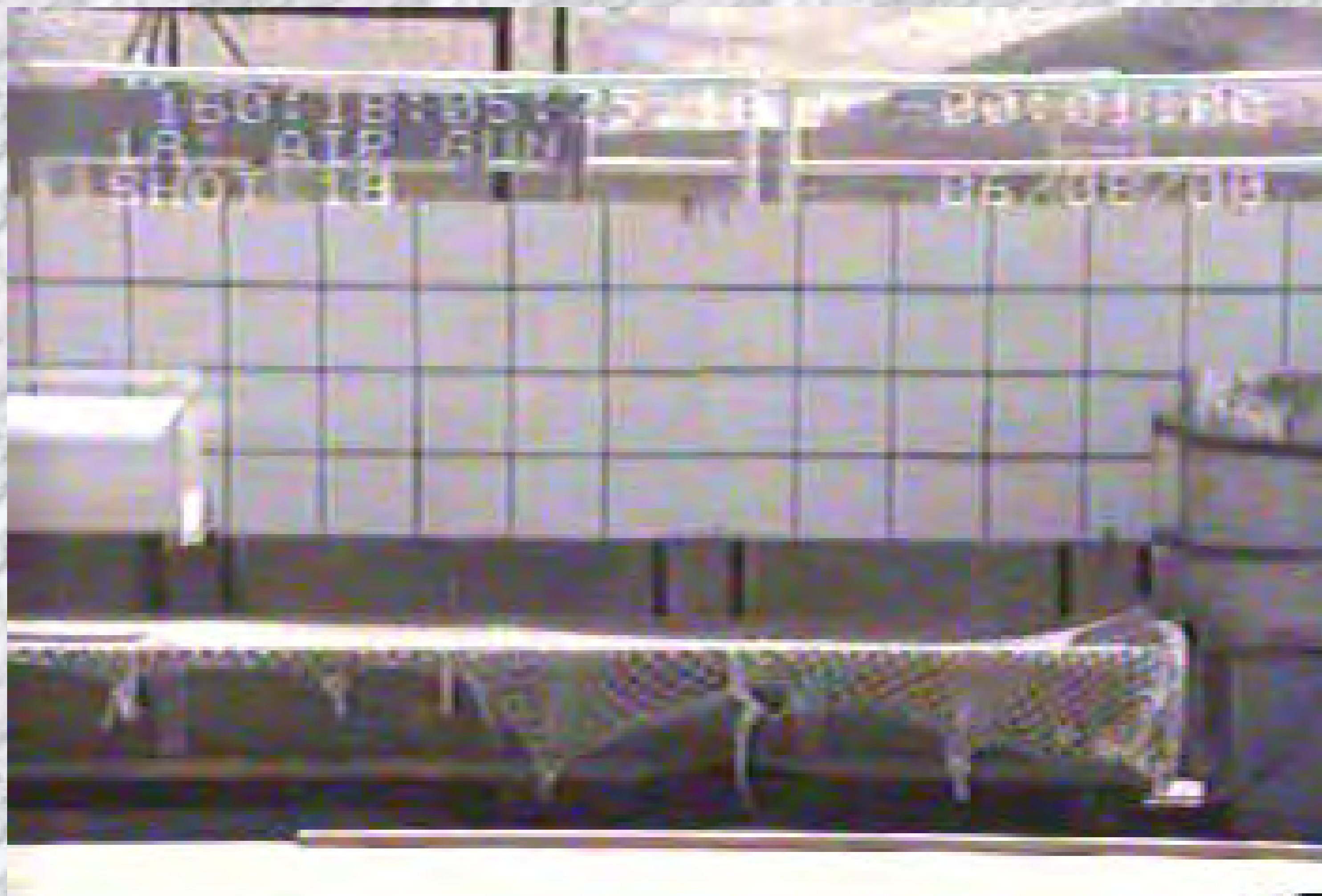
Applications

- Air Gun Test
  - Shot into honeycomb aluminum
  - Velocity: approximately 150 ft/sec
  - Diameter of ball: ~ 6 inches

Applications

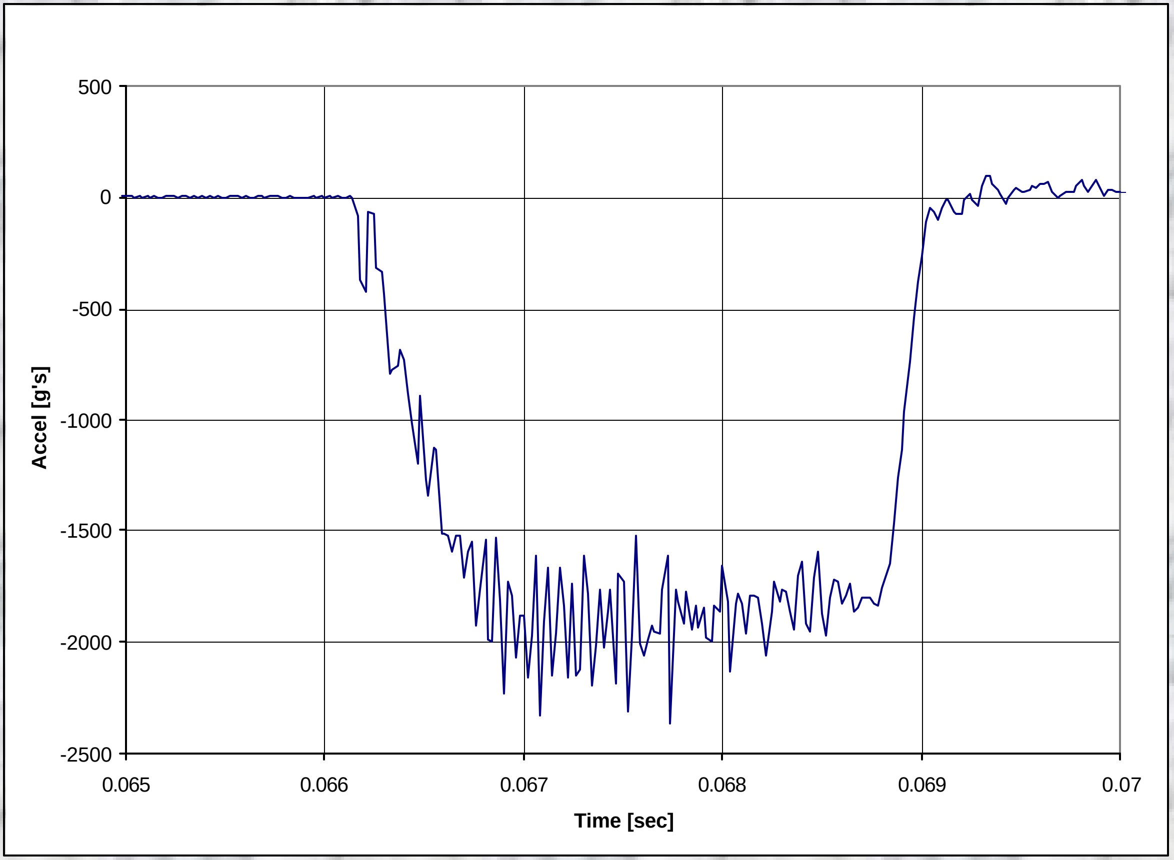


Applications



Applications

- Air Gun Test Data



Applications

- Penetration Testing
  - Scaled Model
  - Super-Sonic
  - Multiple Media

Specifications

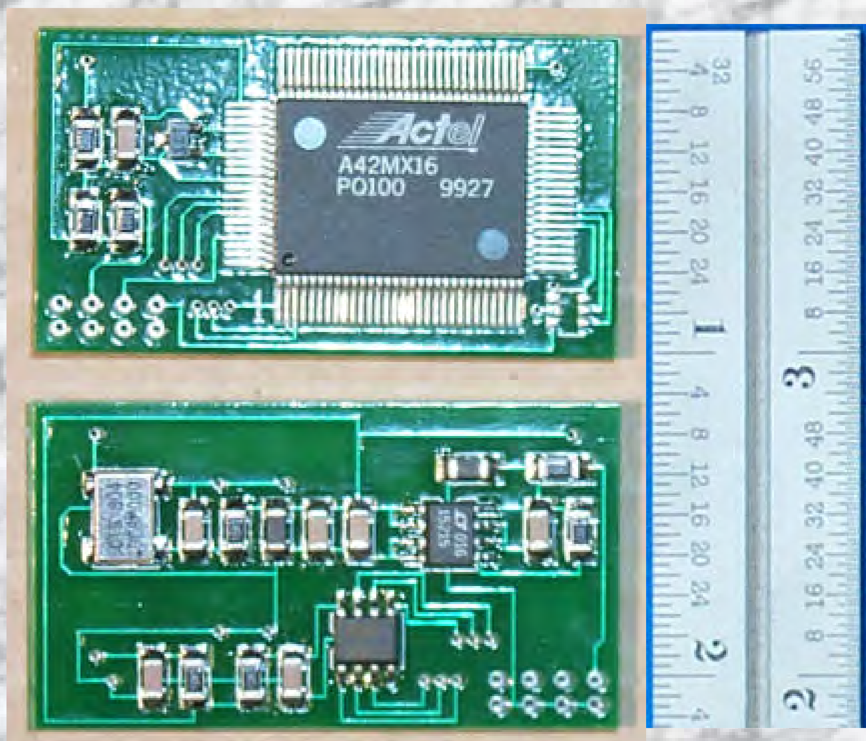
- Memory: 16 x 32k, Non-Volatile.
- Sample Rate: 100k, 10k, 1k, 100 samples per second
- Record Time: 0.328 s, 3.28 s, 32.8 s, 5.44 min
- Input Signal Voltage: 0 to 5 V
- Current Draw: 500 uA (sleep)/ 60 mA (active)
- Data Sheet Available Upon Request

Parts Cost

- Parts cost is $200 to $250 per unit in small quantities.
  - Analog to Digital Convertor - $35
  - Field Programmable Gate Array - $30
  - Non-Volatile Memory - $30
  - Printed Circuit Boards - $25
  - Oscillator - $8 to $15

Future Plans

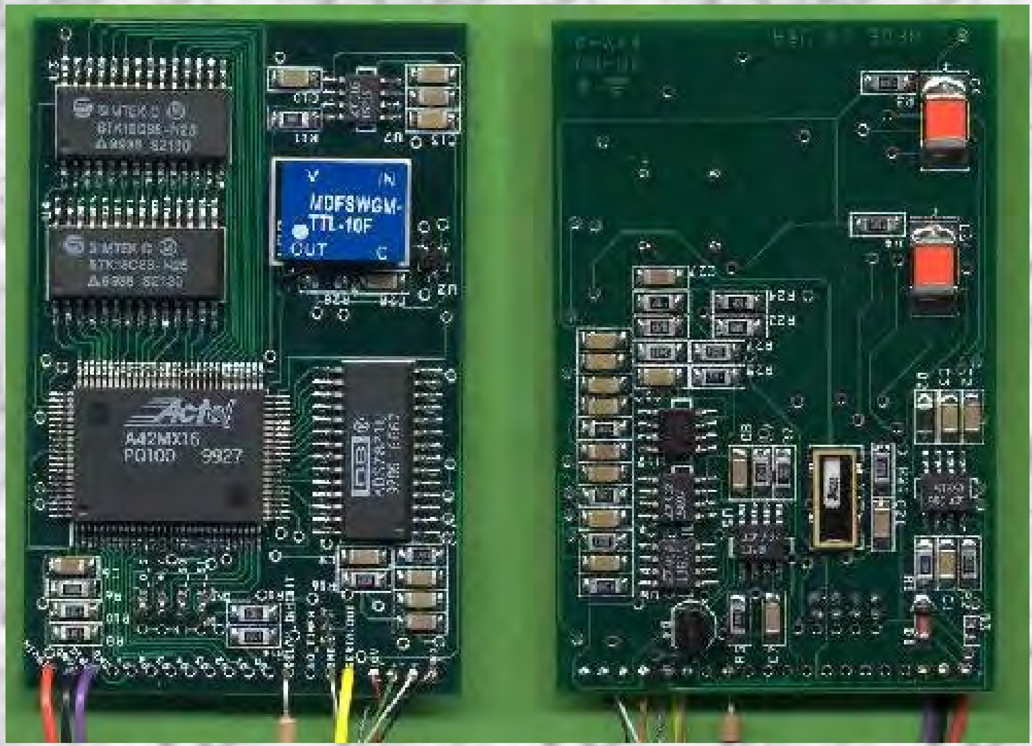
- Smaller Size
- Lower Power



- ASIC Version

Summary

- Survives Shock of Penetration
- Easy to Use Interface
- Low Cost
- Versatile
- Simple



Precision CMOS Clock Oscillator for HI-G Applications

Presented by

Fred Mirow

Chief Engineer

Micro Oscillator, Inc.

Co Author

Dick Mabry

AFRL/MNMF

Eglin AFB

WEB SITE: MICRO-OSCILLATOR.COM

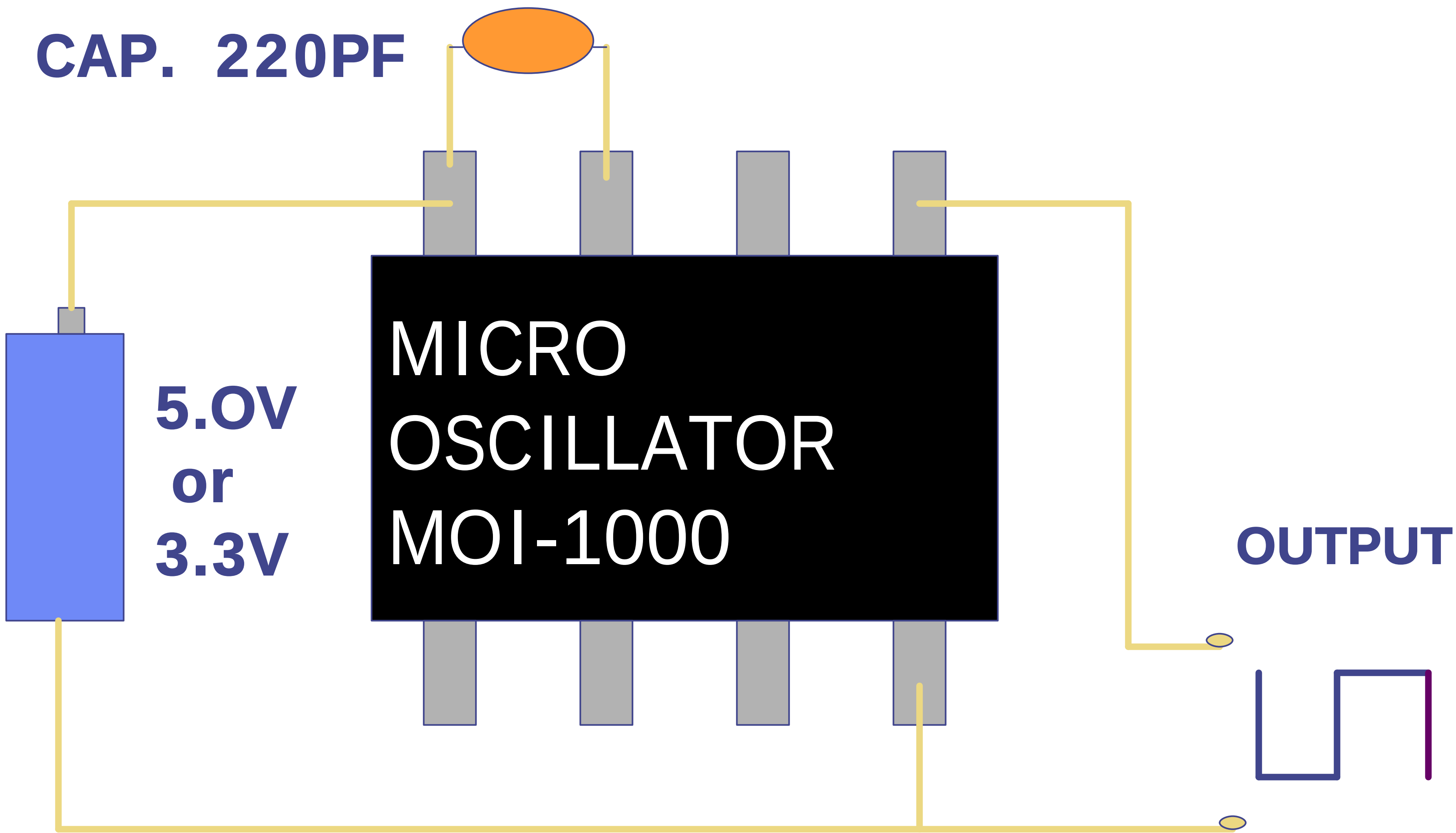
Summary of Discussion

- MOI-1000 CLOCK OSCILLATOR
- COMPARISON OF OSCILLATOR TYPES
- SBIR AF98-220
- MOI-2000 CLOCK OSCILLATOR
- Proposed 32.7KHZ Oscillator
- Summary & Recap

MOI-1000 Clock Oscillator

- *Smallest*
- *Fastest Turn On*
- *Most Rugged*
- *Lowest Power*

OSCILLATOR CIRCUIT

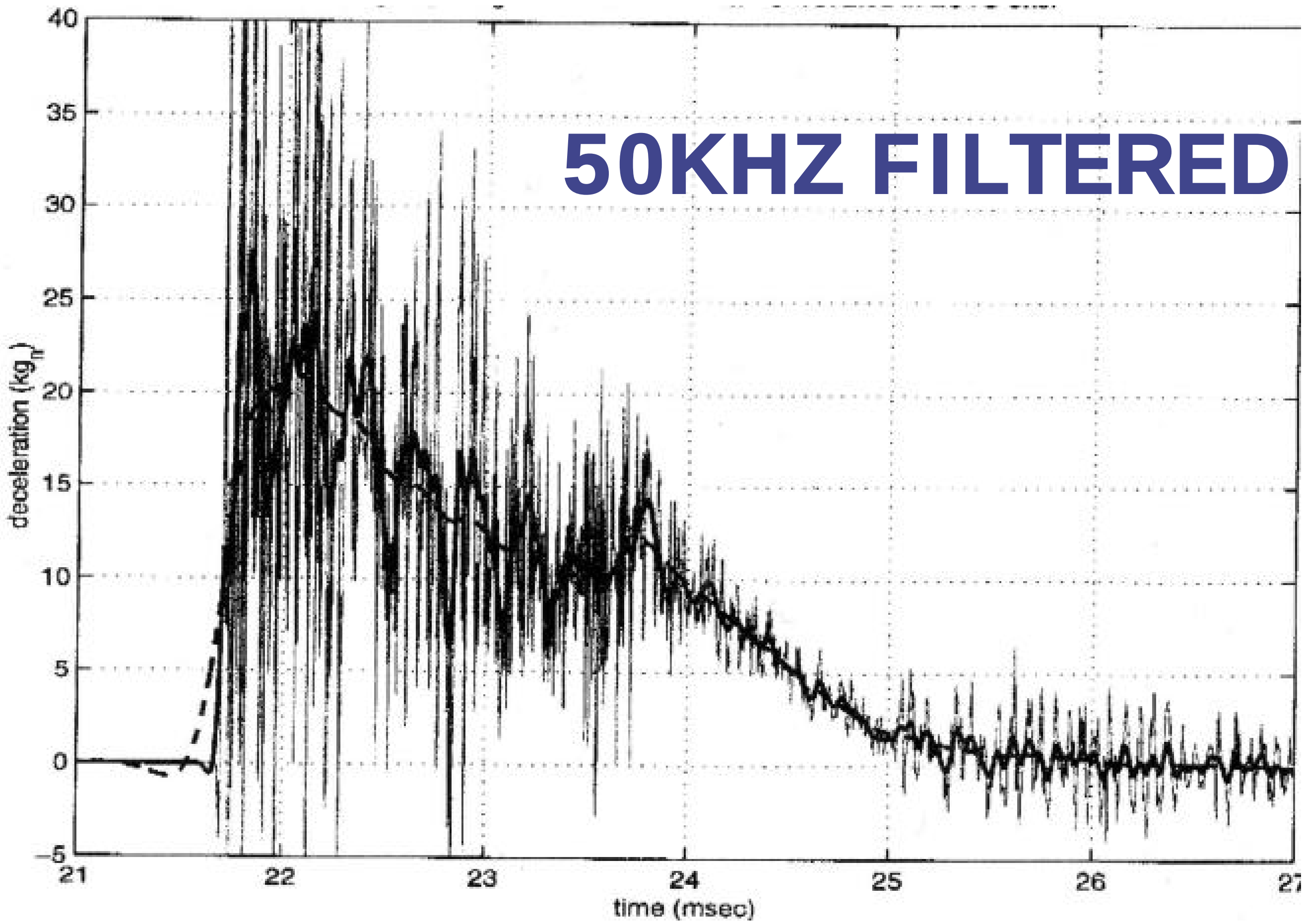


MOI-1000 SPECIFICATION

CMOS IC

SIZE		1.7 X .9 MM
FREQUENCY		16, 20, 24 MHz
FREQUENCY ACCURACY (Temp. & Voltage, Etc.)		
INDUSTRIAL TEMP		0.5%
MILITARY TEMP		1.0%
OPERATING POWER	(5.0V)	25 mW
	(3.3V)	10 mW
OUTPUT, SQUARE WAVE SYMMETRY		55/45%
SHOCK, OPERATIONAL		> 80,000 G
PACKAGE		SO-8, MSO-8 or Bare Die

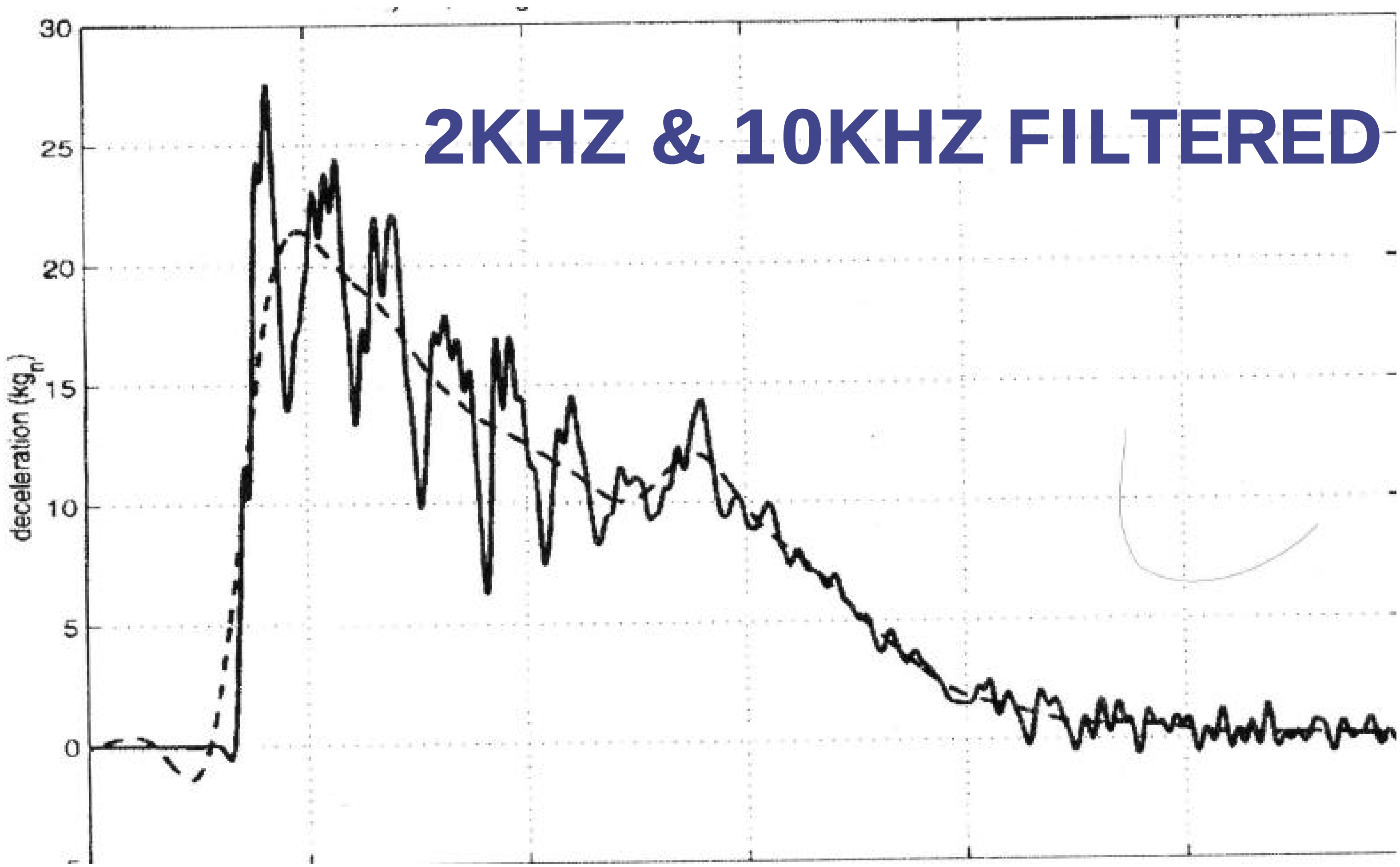
MOI-1000 ACELERATION TEST
(UNIT OPERATING)



155 MM HOWITZER, CONCRETE WALL

PLOT CURTESY OF AFRL/MNMF

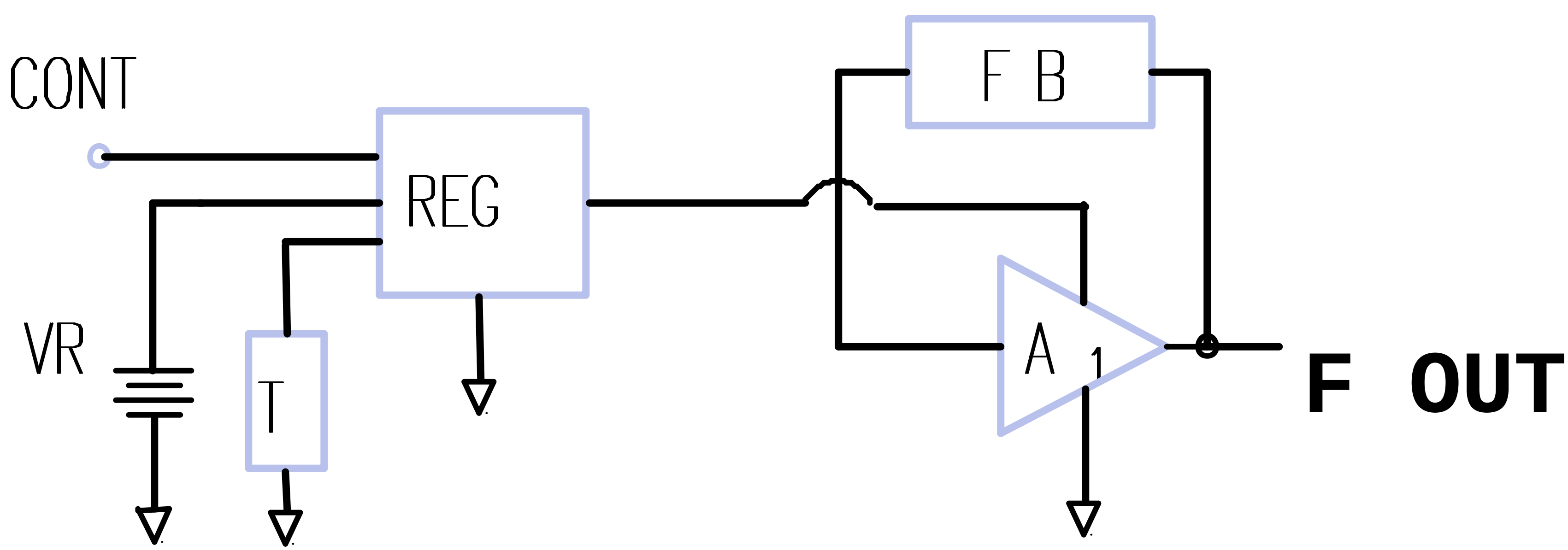
MOI-1000 ACELERATION TEST
(UNIT OPERATING)



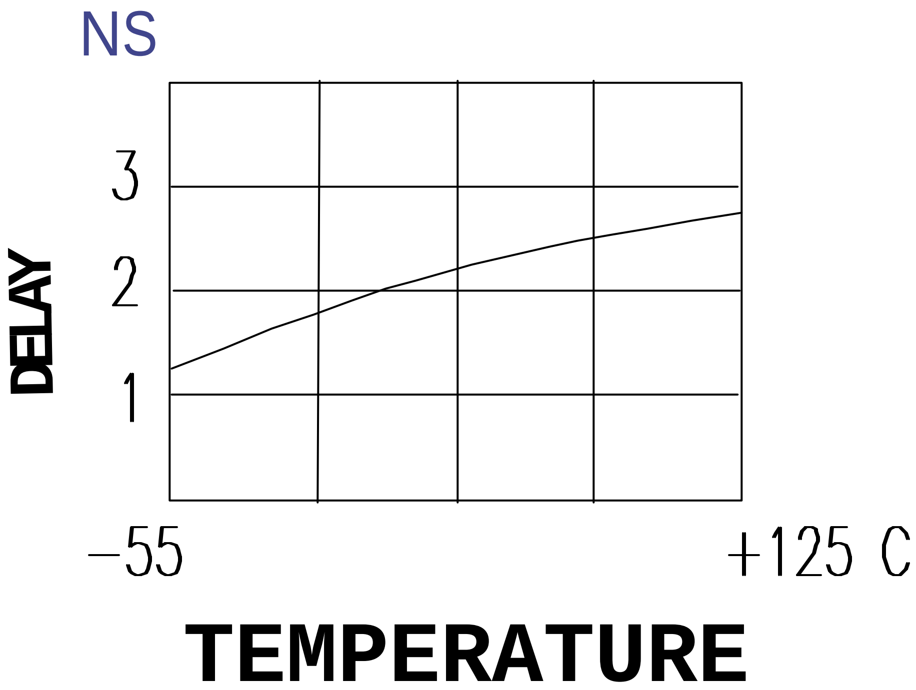
155 MM HOWITZER, CONCRETE WALL

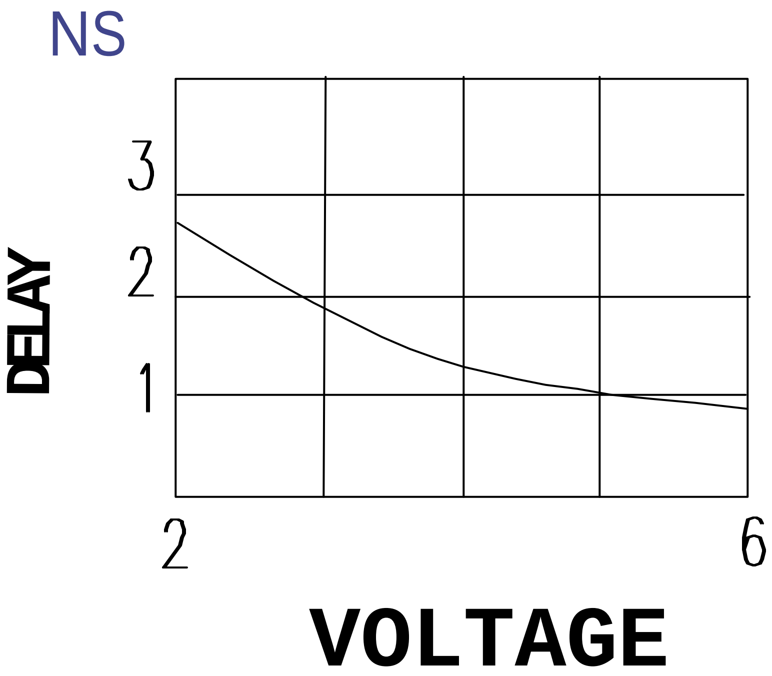
PLOT CURTESY OF AFRL/MNMF

MOI-1000
CLOCK OSCILLATOR
SYSTEM BLOCK DIAGRAM



PROPAGATION DELAY TIME VARIATIONS





CLOCK OSCILLATOR COMPARISON CHART

	MICRO OSCILLATOR	CRYSTAL CLOCK	CERAMIC RESONATOR
FREQ. TOL.	MEDIUM	HIGH	MEDIUM
SIZE (mm)	.9 x 1.7	5 x 7	2.8 x 6.5
HYBRID	YES	NO	NO
RUGGEDNESS	VERY HIGH	LOW	MEDIUM

MOI-1000 ADVANTAGES

1: COMPLETE CLOCK OSCILLATOR
2: SMALL SIZE, BARE DIE OR S0-8
3: NO START UP PROBLEMS
4: NO FREQUENCY JUMPING
5: 3.3 V OR 5.0 V AVAILABLE
6: +/- 0.5% TOLERANCE INDUSTRIAL
7: +/- 1.0% TOLERANCE MILITARY

MOI-1000 DISADVANTAGES

1: NOT AS ACCURATE AS CRYSTAL

EXISTING APPLICATIONS

PROGRAMMAMBLE PROJECTILE FUZE

CRITICAL REQUIREMNENTS MET-

OPERATIONAL IN HIGH G ENVIRONMENT

FAST TURN ON TIME

BARE DIE FOR HYBRID PACKAGING

LOW OPERATING POWER

HARD TARGET FUZING

CRITICAL REQUIREMNENTS MET-

OPERATIONAL IN HIGH G ENVIREMENT

LOW OPERATING POWER

SBIR AF98-220

PURPOSES:

1) IMPROVE MOI-1000:

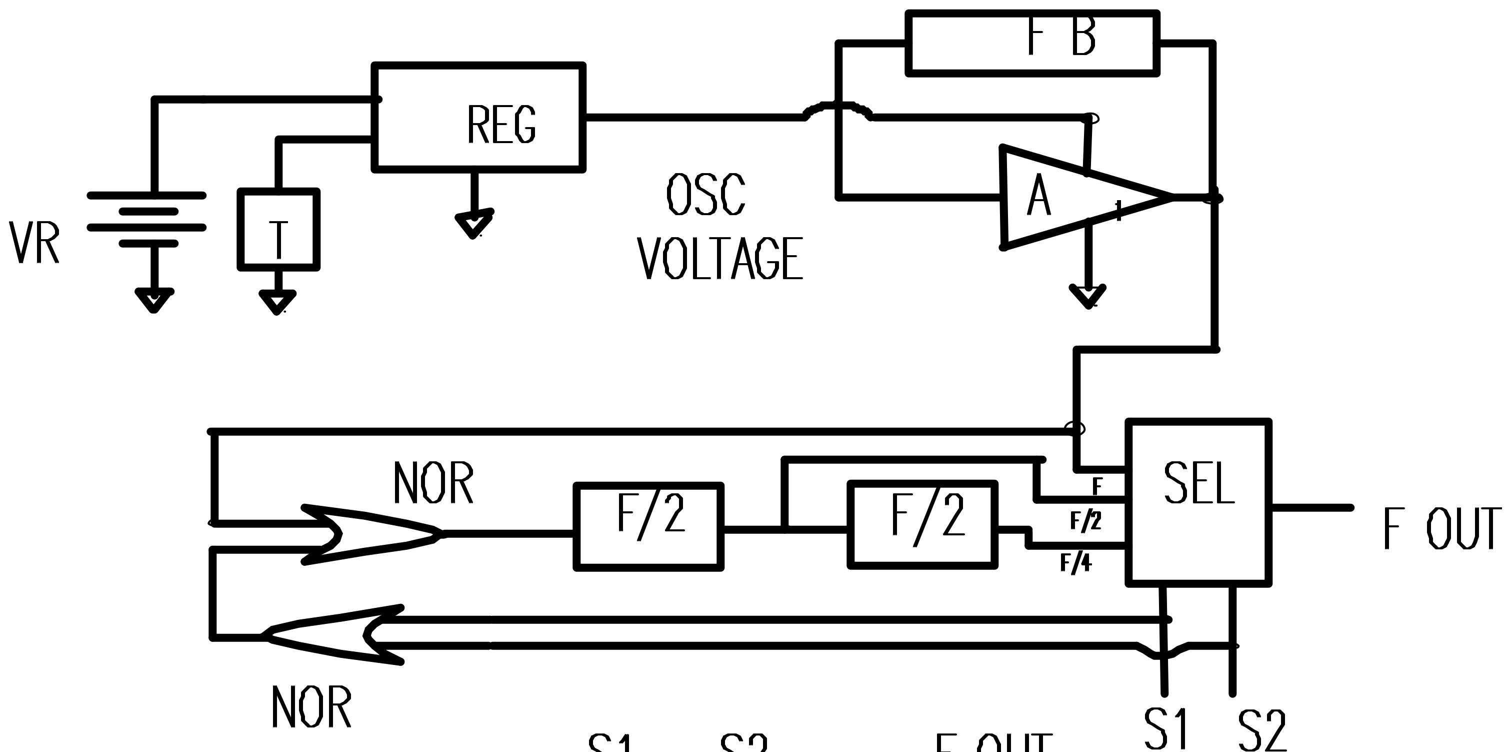
REDUCED OPERATING POWER
WIDER FREQUENCY RANGE

2) DEVELOP 32.7KHZ VERSION

SBIR TIMER BASE SYSTEM SPECIFICATION

	SYSTEM 1	SYSTEM 2
VOLTAGE	5V +/-5%	3.3V +/-5%
CURRENT	1 MA MAX	1 MA MAX
FREQ. TOL.	+/-1% ABSOLUTE	+/-1% ABSOLUTE
FREQ. RANGE SINGLE FREQ.	14.0 TO 20.0 MHZ	3.5 TO 5.0 MHZ
OPERATING TEMP.	-55 TO 125 ^{O}C	-55 TO 125 ^{O}C
OUTPUT DRIVE	2 HC CMOS	2 HC CMOS

MOI-2000 CLOCK OSCILLATOR
SYSTEM BLOCK DIAGRAM



S1	S2	F OUT
0	0	F
1	0	F/2
0	1	F/4

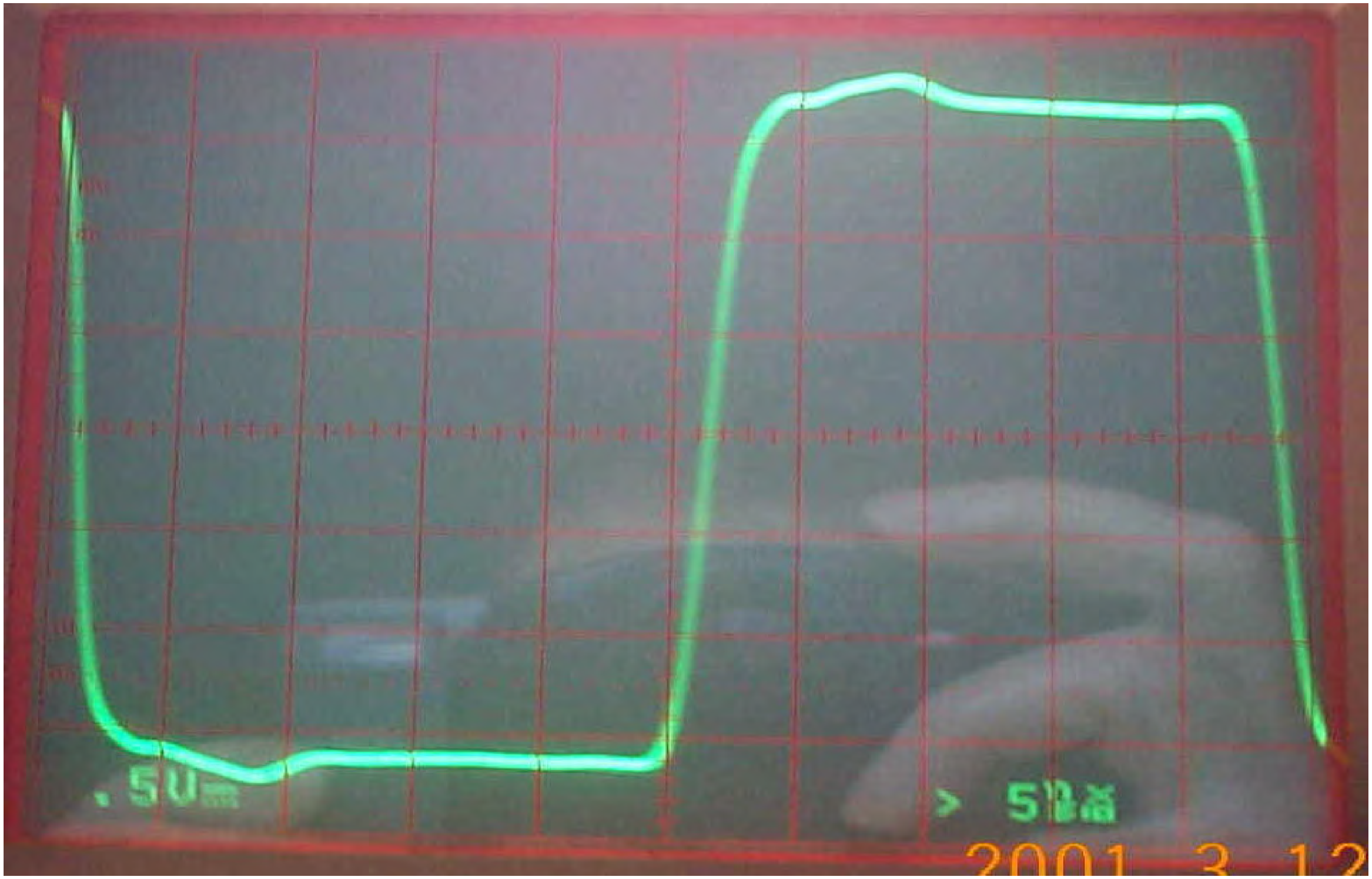
COMPARISON
OF
MOI-1000 TO MOI-2000

	MOI-1000	MOI-2000
FREQ.	14 to 24MHz	4 to 20 MHz
CURRENT		
5.0 VOLTS	5mA	1.6mA
3.3 VOLTS	3mA	1ma
TOL.	+/-1%	+/-1%

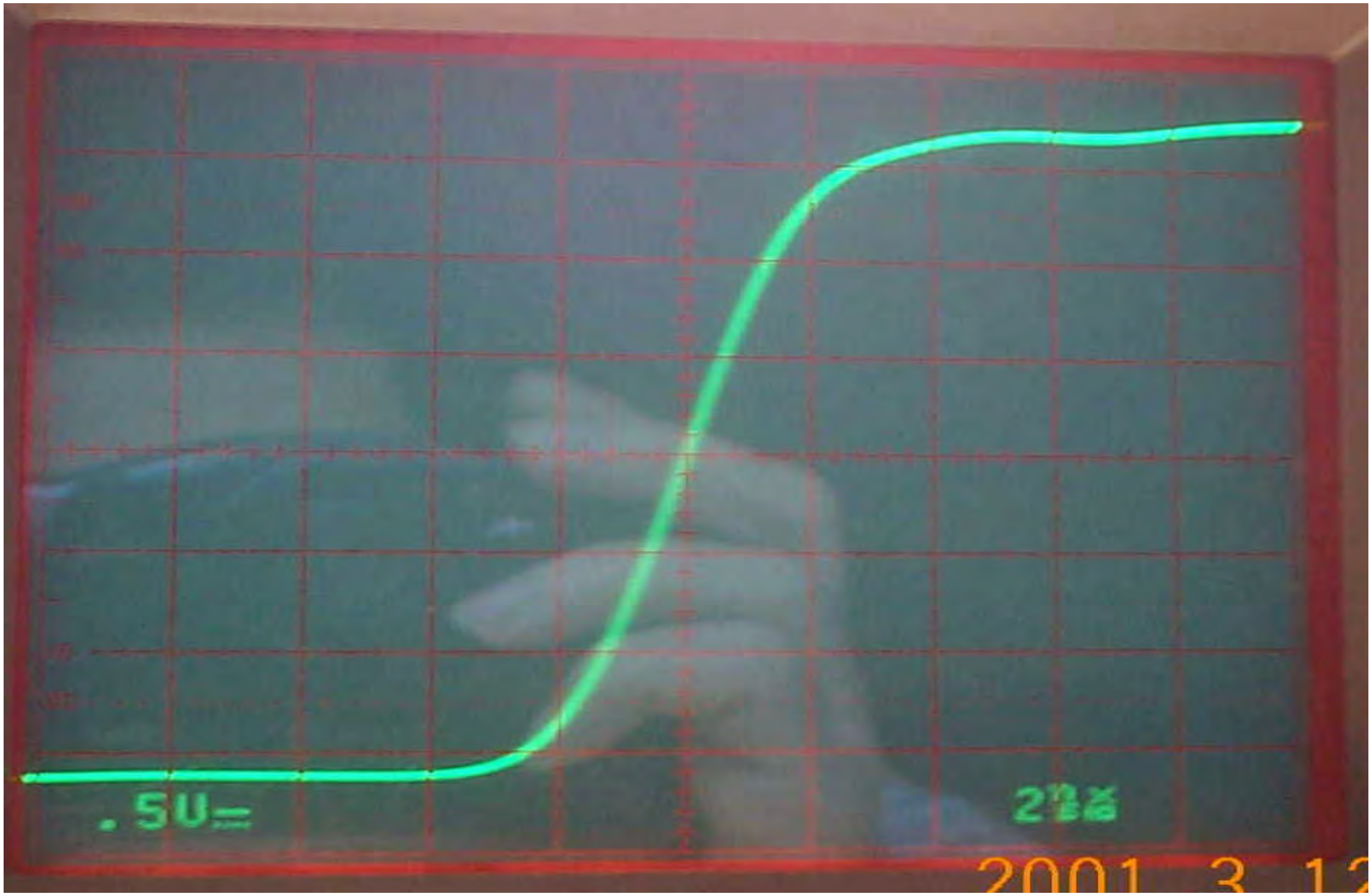
MOI-2000 PREPRODUCTION MEASURED PERFORMANCE

VOLTAGE	5	3.3
CURRENT	2.2 Ma	1.4 Ma
FREQUENCY	16 MHz	10 MHz
FREQ. TOL. -55 - 125^{o}C	$\pm$ 1.0%	$\pm$ 1%

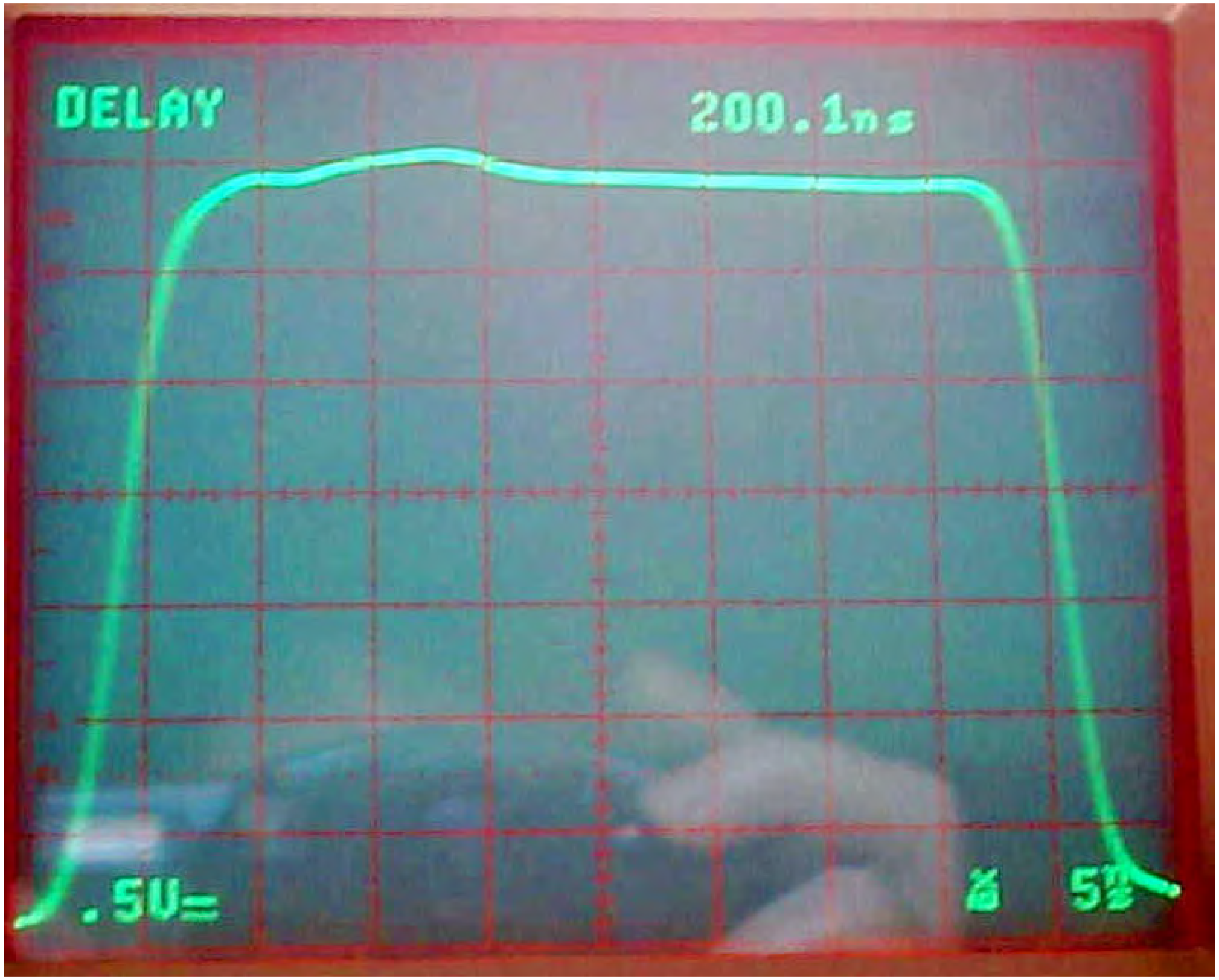
MOI-2000 OSCILLATOR OUTPUT
3.3V 12PF LOAD, 53/47% DUTY CYCLE



MOI-2000 OSCILLATOR OUTPUT
3.3V 12PF LOAD, 2 NSEC/DIV



MOI-2000 OSCILLATOR OUTPUT DELAYED 3.3V 12PF LOAD



32.7 KHz TIME BASE SYSTEM SBIR SPECIFICATION

Operating Voltage	3.3v or 5V 5%
Operating Current	0.2 ma max
Frequency Tol.	+/- 1%
Frequency	32.7 KHz
Operating Temp.	-55 to 125 c
Package	S0-8

OSCILLATOR AVAILABILITY SCHEDULE

MOI-2000		
	5V	JULY 2001
	3.3V	NOW
32 .7KHz		JULY 2002

Summary & Recap

MOI-1000

5 YEARS OF PROVEN
PERFORMANCE IN
HI-G APPLICATIONS

MOI-2000

SAME PROVEN TECHNOLOGY AS
MOI-1000 AT A MUCH LOWER
OPERATING POWER LEVEL

Programme Objectives

- Obsolescence
- Tooling
- Test Gear
- Safety
- Reliability
- Qualification
- 1st Article
- Production

TEAM FUZING

TEAM FUZING

Qualification Programme

Sub System Tests

HARDWARE | ENVIRONMENT INTERNAL | INTERNAL TEST (TEST/INSPECTION)

Hardware

3 off sub-assys (Electronic Module & Cover Plate)
KDI

3 off sub-assys (S&A Module)
RAYMOND

3 off Vibration
DAYRON

3 off sub-assys (Booster)
SEI

Environment Internal

QUALIFICATION TESTS

a) 3 hrs hot temperature (+85°C)

b) 3 hrs cold temperature (-40°C)

3 Systems -Dayron
3 Boosters - SEI

- 3 hrs random vibration ($0.04g^2$/Hz between 20 Hz and 2 kHz) (Hot/Cold)

a) 1.5 hrs hot temperature (+85°C)

b) 1.5 hrs cold temperature (-40°C)

Internal Test (Test/Inspection)

KDI

a) Visual Inspection - Pre
b) Functional Test -Pre
c) Visual Inspection - Post
d) Functional Test - Post

RAYMOND

a) Visual Inspection - Pre
b) Functional Test -Pre
c) Visual Inspection - Post
d) Functional Test - Post

DAYRON

a) Visual Inspection – Pre
b) Functional Test -Pre
c) Visual Inspection – Post
d) Functional Test - Post

SEI

a) Visual Inspection prior to test
b) Visual Inspection following test
c) Firing into witness plate
d) Evaluation results

Sequence 1

a) & b) prior to test

Salt Fog

LIVE	INERT
3 off	3 off
a) & b)	a) & b)

Ascertains the ability to resist the effects of a moist, salt-laden atmosphere.
Subjected to a specified controlled environment for 24 hours.
(MIL-STD 331A Test 107.1)

a) Visual check
b) Impedance check

Contamination

LIVE	INERT
3 off	3 off
a) & b)	a) & b)

Determines the resistance of equipment to contamination from fuels, lubricants, hydraulic fluids, de-icers, solvents, fire-fighting agents & fresh/saltwater.
(Def Stan 00-35)

a) Visual check
b) Impedance check

Accelerated Ageing

LIVE	INERT
3 off	3 off
a), b), c), d)	a), b), c), e)

To determine the ability of equipment to withstand prolonged storage at extreme (hot & cold) temperatures.
(MIL-STD 331A Test 112.1 Procdr. 1)

a) Visual check
b) Impedance check
c) Leak Test
d) Fired
e) Strip & Examine

SEI | DAYRON | KDI | RAYMOND

FMU-139B/B

- Further contract for 3000 FMU139B/B fuzes for a European country.
- Need to address the Power consumption issue to meet the FFCS requirement for the Navy.
- Potential further orders for other European and Middle/Far East Countries.

TEAM FUZING

FMU-139 B/B

Mitigation of FMU-139 Component Obsolescence

John N. Minnich, KDI Electrical Engineer

Ted Lewis, KDI Sr. Staff Engineer

SEI DAYRON KDI RAYMOND

FMU-139 Chronology

- FMU-139A/B
  - Full scale procurement commenced in 1985
  - Last procurement was in 1993
- SAU - A FMU-139A/B derivative
  - Original build circa 1989-1992
  - Team Fuzing awarded contract in 1999, delivered units in 2000.

Two Major Design Challenges

- Replacing the obsolete 4-bit microcontroller.
  - Reverse engineering the logic without source code.

- Improving the operating duration when powered in FFCS mode.

Replacing the Microcontroller

- FMU-139 A/B based upon COP320C
  - 4 bit, CMOS design
  - Industrial temp range (-40 °C to 85 °C)
  - Low current: 100 µA at 5V with f_{clk} = 32 KHz

- KDI evaluated 8-bit µcontrollers and FPGAs
  - Architecture A: 8-bit µcontroller + ASIC
  - Architecture B: Two FPGAs / ASICs

Reverse engineering the fuze logic.

- Drawing package did not include source code.
  - ROM Object code available as printed media only !

- KDI attempted to reverse assemble this ROM
  - Output is uncommented assembly code.
  - Output appeared to have reverse assembly errors.

- KDI abandoned the µcontroller approach due to these issues.

What legacy documentation was available to KDI?

- FMU-139A/B Mil. spec. MIL-F-85815A(AS)
  - FFCS and Turbine operating modes
  - High & low drag arm times
  - Impact or proximity detection requirements
  - Impact or Prox function delay timing
- Navy DWG package 1379ASxxx
- SAU DWG package SK105xxxx

What information was missing ?

- Drawing package did not include source code.
  - Internal self tests
  - Detailed DUD logic requirements
  - Digital filtering / signal conditioning of inputs

To address these “holes” KDI requested a Commercial Service Agreement with the Navy

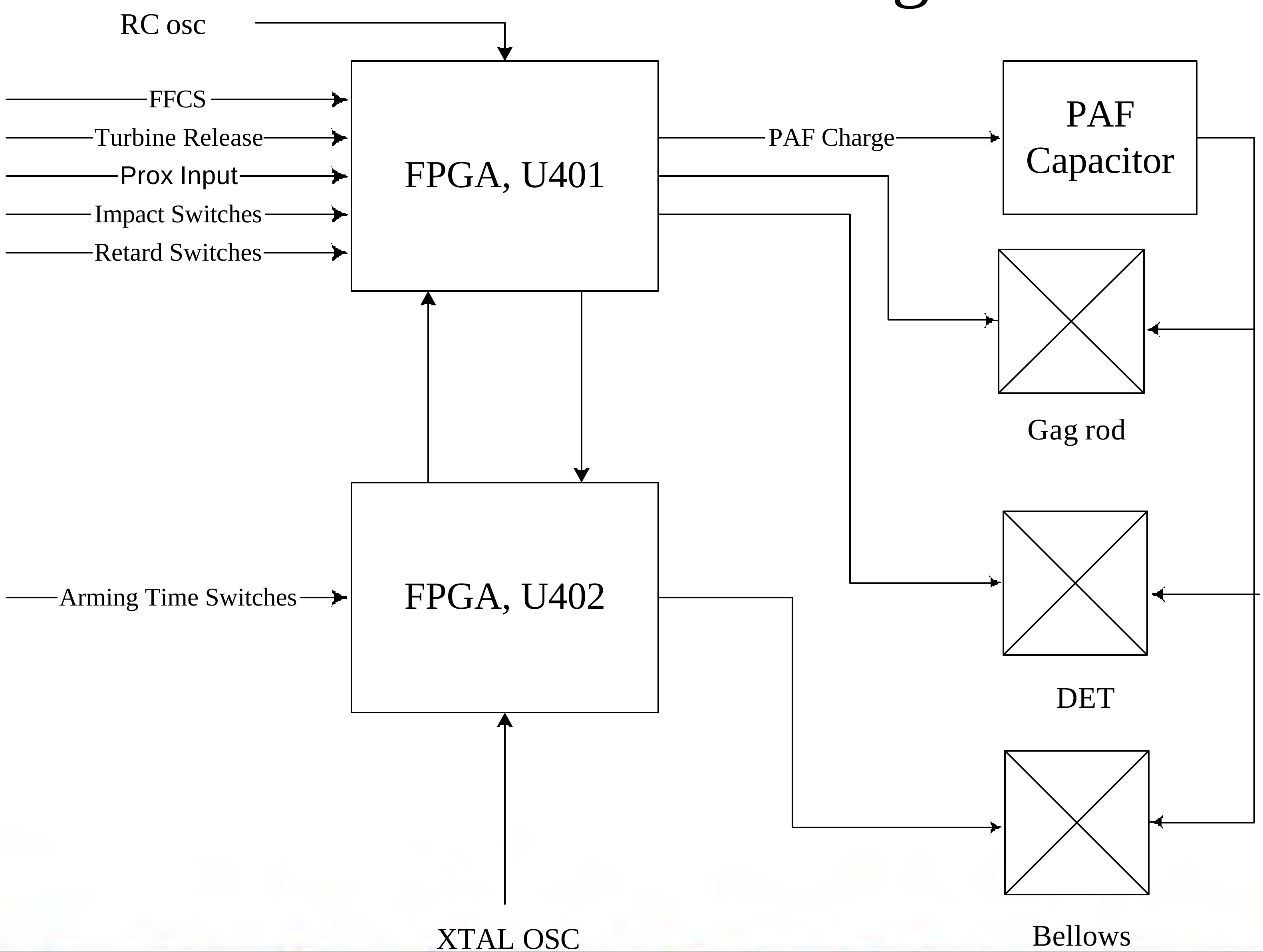
SAU Implementation

- 2 FPGAs replace the μcontroller and ASIC
  - FPGA, U_{402} initiates Gag rod and DET circuitry
  - FPGA, U_{401} initiates Bellows circuitry

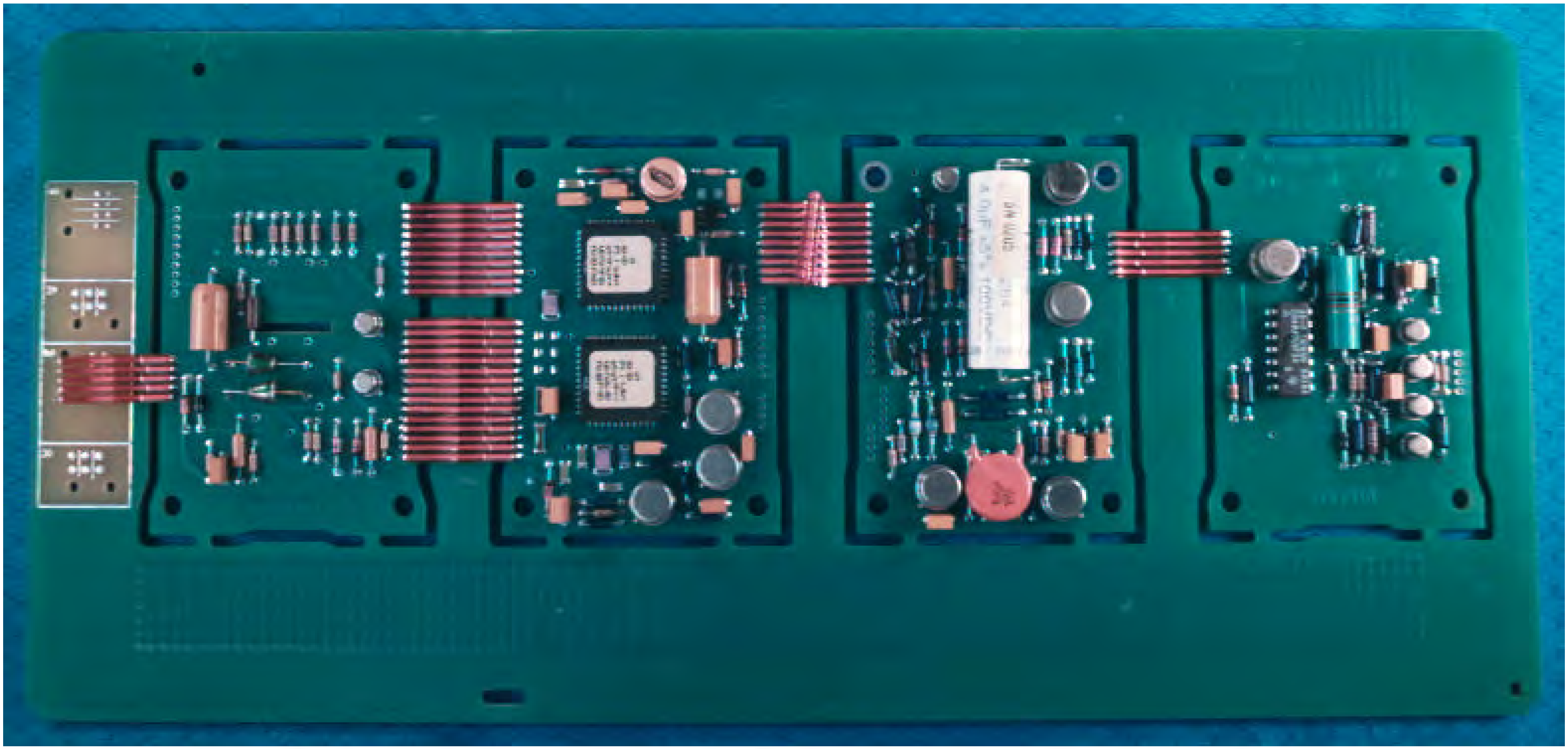
- Switching regulator based on FMU-139 A/B "JANTX" implementation rather than SAU

- Components are predominantly "through-hole"

FPGA Partitioning



SAU Production Panel

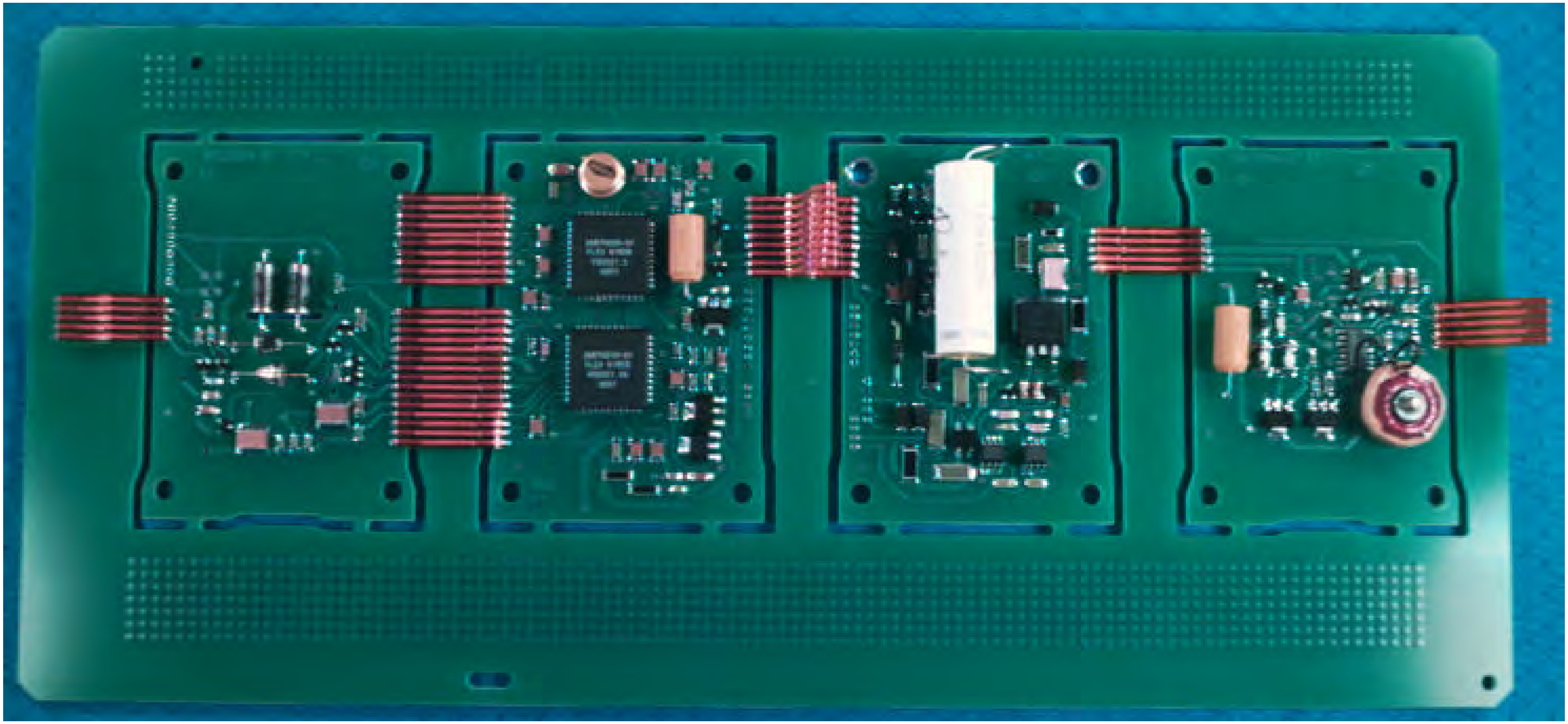


SEI DAYRON KDI RAYMOND

FMU-139B/B Implementation

- 2 ASICs replace the SAU FPGAs
- KDI improved the switching regulator
  - Higher efficiency toroidal inductor
  - All 3 select resistors eliminated
- Components are predominantly surface mount

FMU-139 B/B Prototype Panel



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FFCS Mode Energy Balance

$$\frac{1}{2}\, C_1\, V_1^{\,2} = \frac{3}{2}\, C_2\, V_2^{\,2} + (V_{bus})\,(i_{ave})\,(t)$$

C1 ➔ Main energy storage capacitor
C2 ➔ PAF capacitor

Let: $C_1 = 4.0\ \mu F$, $C_2 = 47\ \mu F$
$V_1 = 195$, $V_2 = 9$, $V_{bus} = 3.8$

For: $t = 60$ seconds, $i_{ave} = 308\ \mu A$

TEAM FUZING

Benefits of the Team Fuzing Design Changes

- Operating duration when powered in FFCS mode exceeds the original FMU-139 A/B
- Extended operating duration facilitates higher altitude bomb release
- Modern and reliable manufacturing process.
- Potential cost reduction.
- Based on proven design.

SEI DAYRON KDI RAYMOND

45th Annual NDIA Fuze Conference

Mechanical Packaging of the EX 433 Proximity Fuze for Submunitions

18 April 2001

Eugene Marquis
NSWCDD G34
Fuze Branch

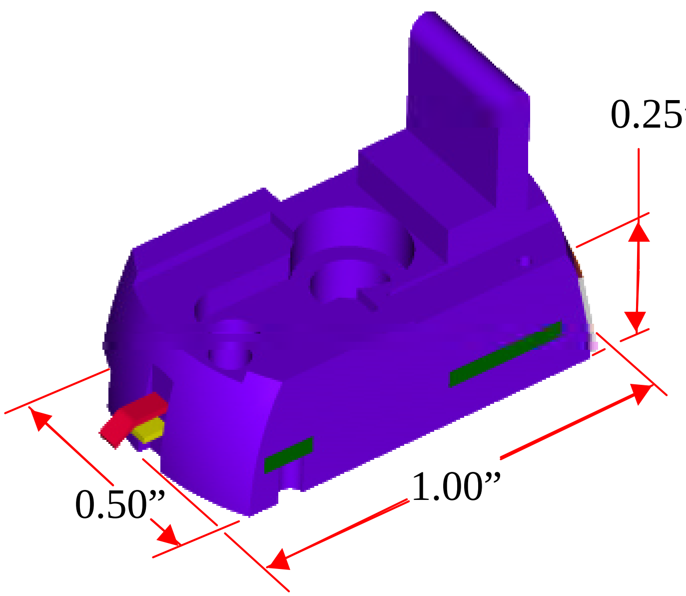
MK 45 MOD 4
Gun Mount

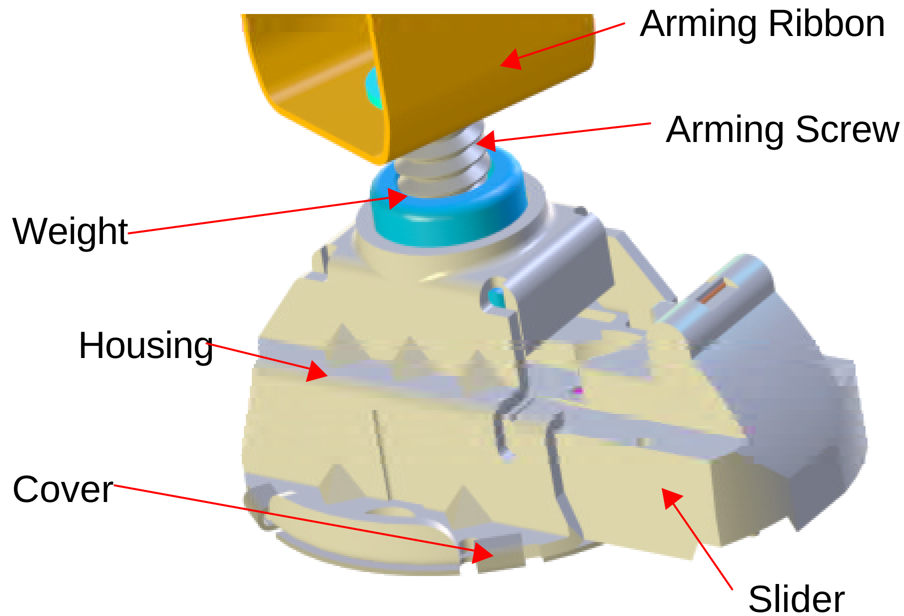
EX 3 Submunition
w/ EX 433 Proximity
Fuze

ERGM: Extended Range Guided Munition

M80 PIP Objective

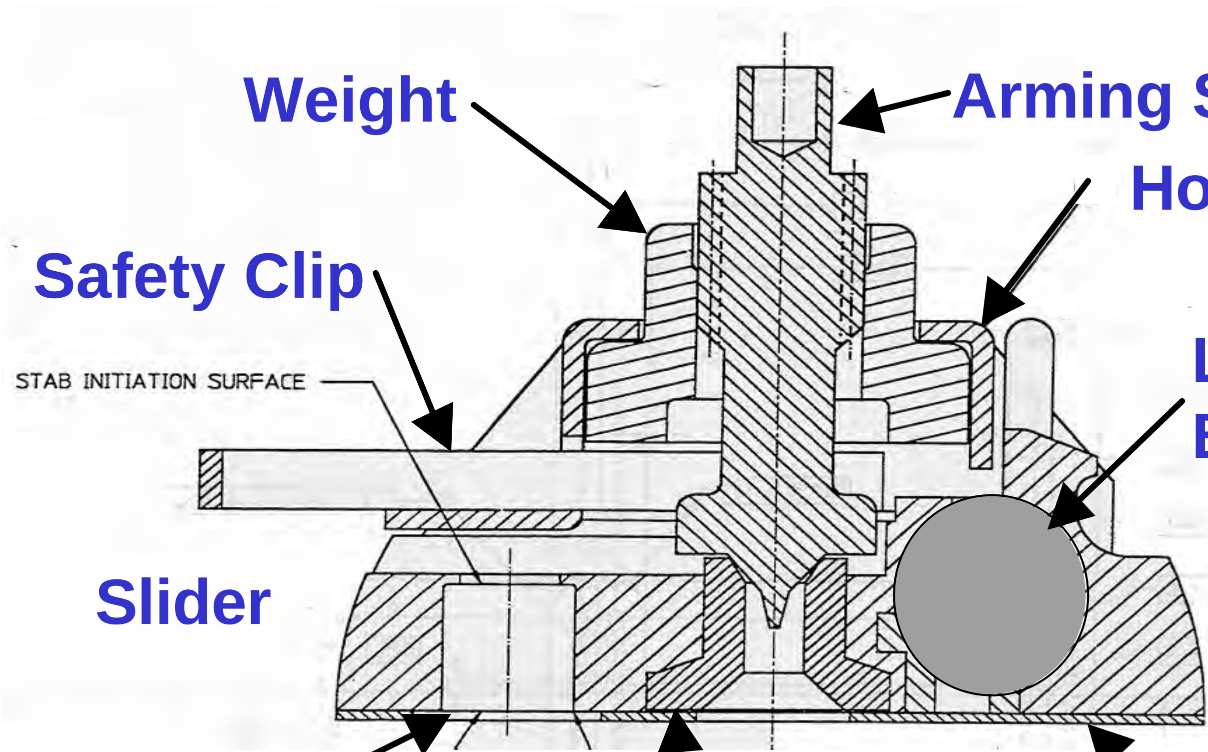
- **To package the electronics and mechanical components of the Proximity Fuze in the shape and size of the current M234 SD Slider for the M80 Submunition for ERGM**
  - One-for-One replacement of current Slider





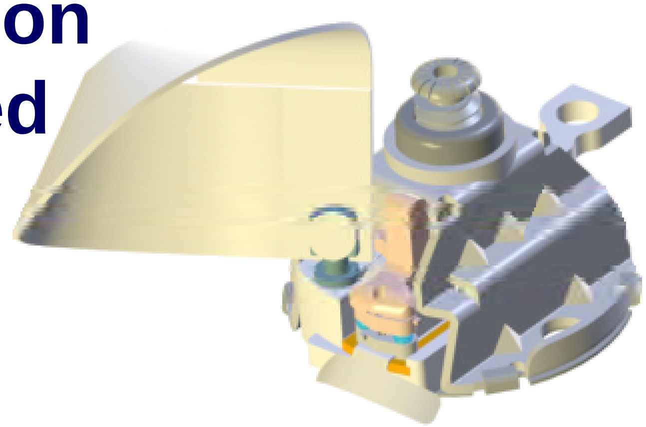
M234 Self-Destruct Fuze

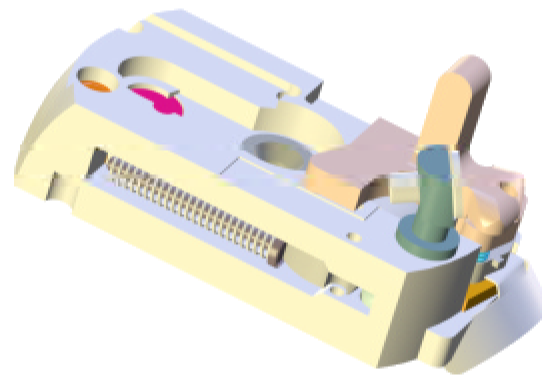
M80 w/
M234

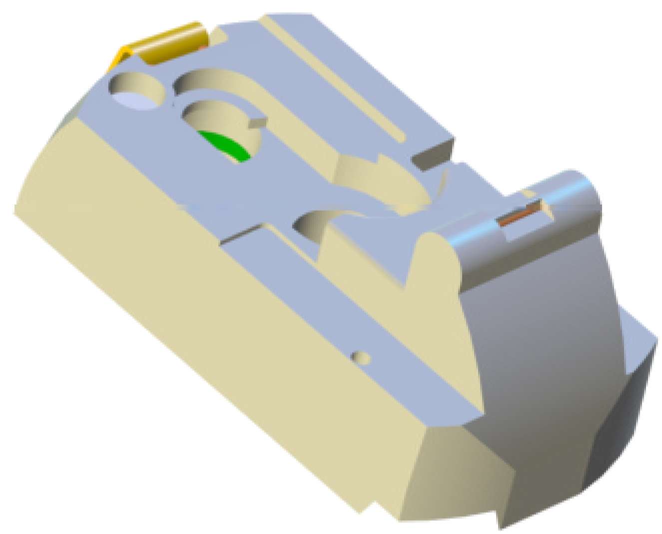


Parts removed from M234

- **Battery Activation System removed**
  - Spring
  - Lever (hammer)
  - Pivot
  - Spiral Ribbon Assy
  - Ball
- **Shunt and Safety Pin removed**
- **Battery Cover removed**



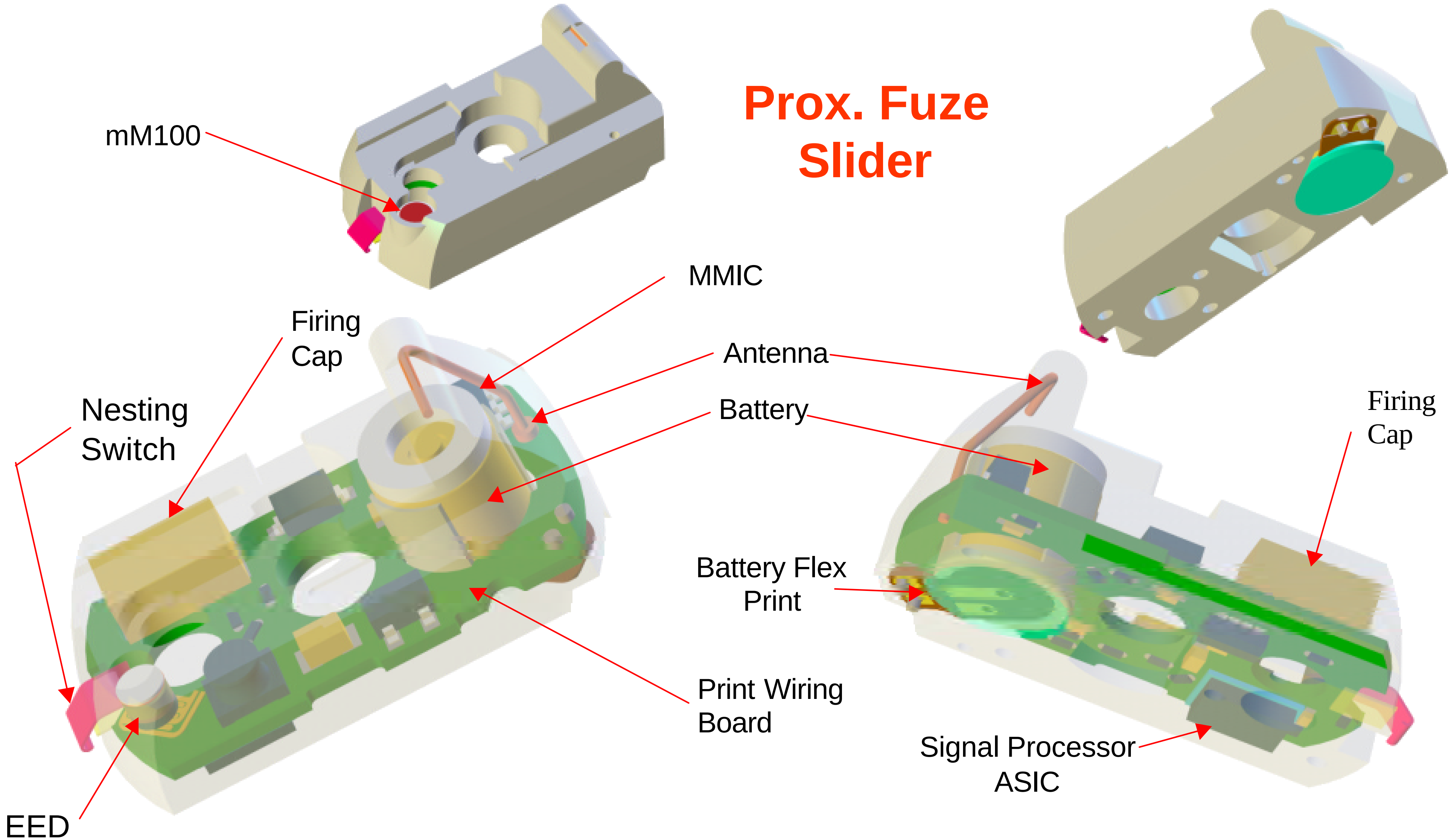




Functions

- **Primary Mechanical Safety And Arming Features of the M234 SD Fuze Retained**
  - Impact Firing System is now the backup
- **Prox Fuze electronics will use two timers**
  - Separation Timer
    - Ensures proper event sequence
      - Battery activation and unnesting
  - Self-Destruct Timer
    - Provides the current cleanup capabilities of M234 SDF
      - Self-Neutralization or Self-Destruct

Major Components Layout



Battery

Nesting Switch

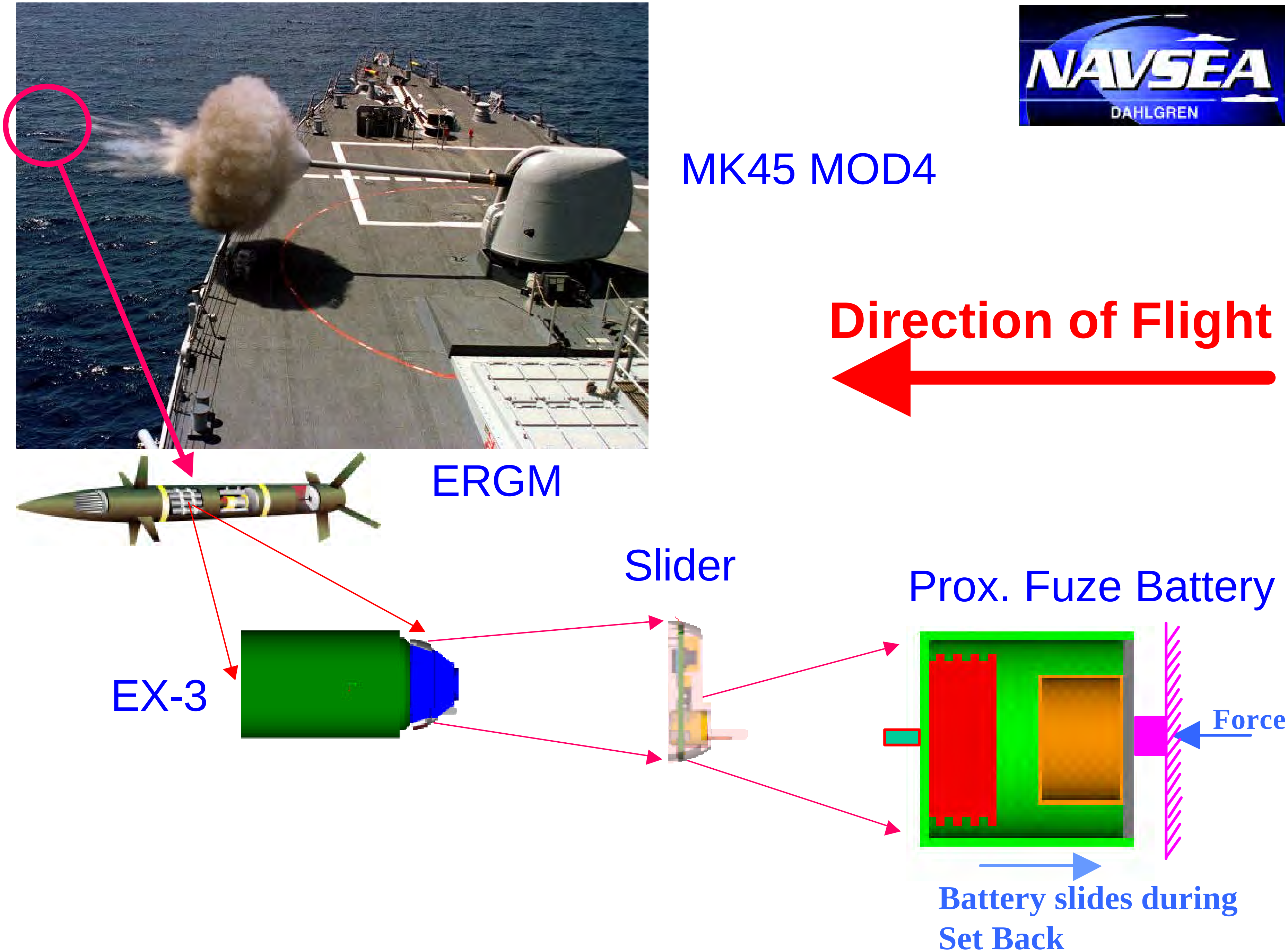
mM100

NAVSEA DAHLGREN

Battery

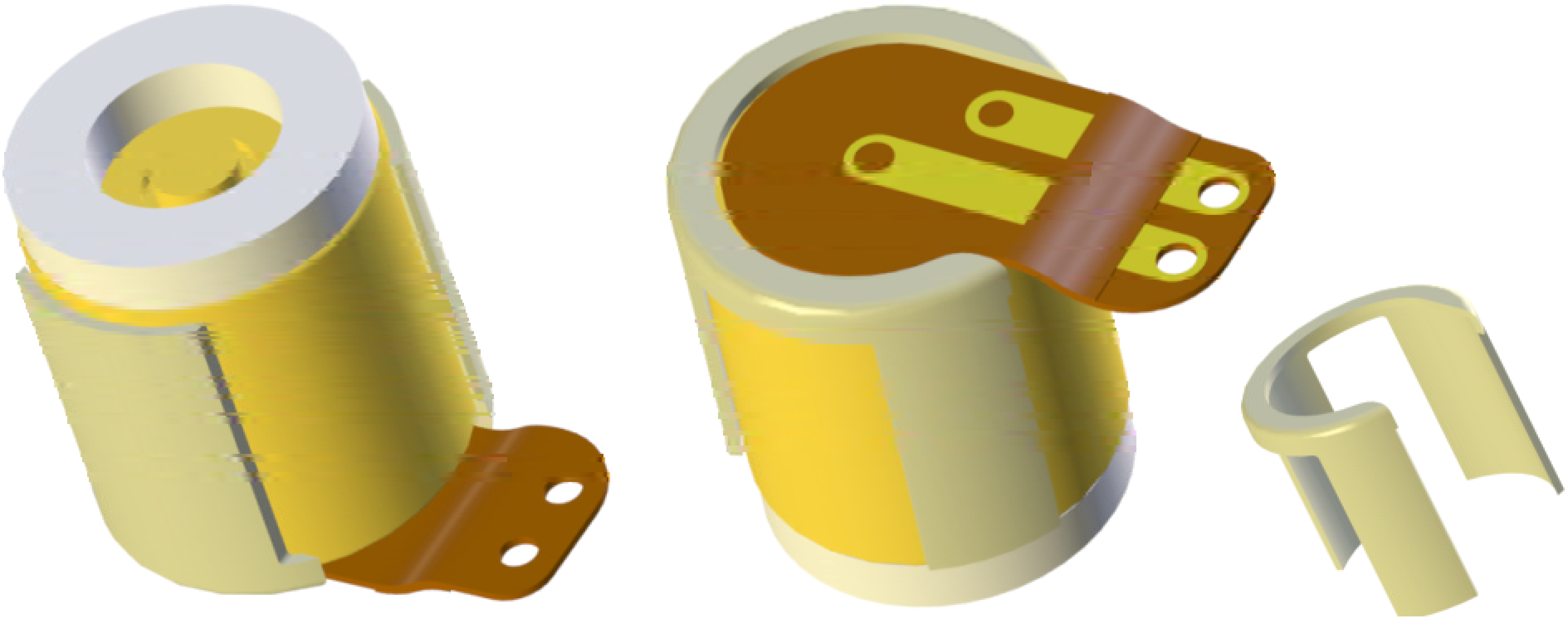
Nesting Switch

mM100

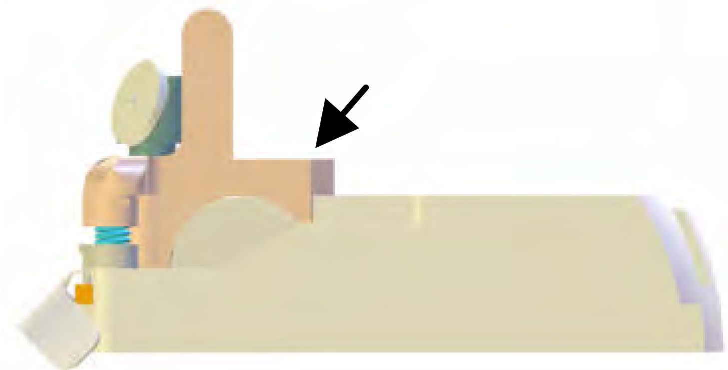

NAVSEA
DAHLGREN
MK45 MOD4
Direction of Flight
ERGM
Slider
Prox. Fuze Battery
EX-3
Force
Battery slides during
Set Back

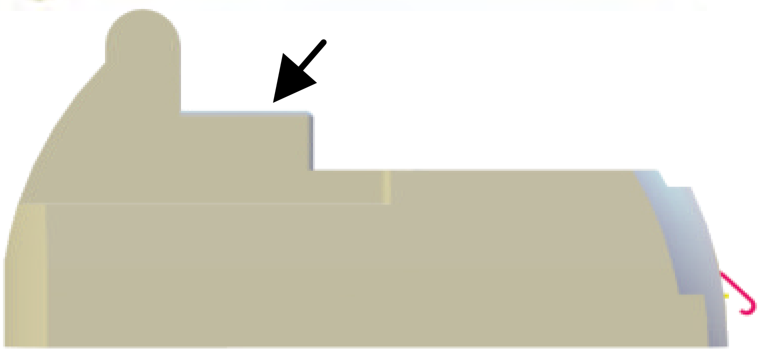
Battery

- Requires a small nub to be molded into the plastic or a feature on the Battery
- Flex Print connection to Print Wiring Board
- Weight may be added to increase activation energy

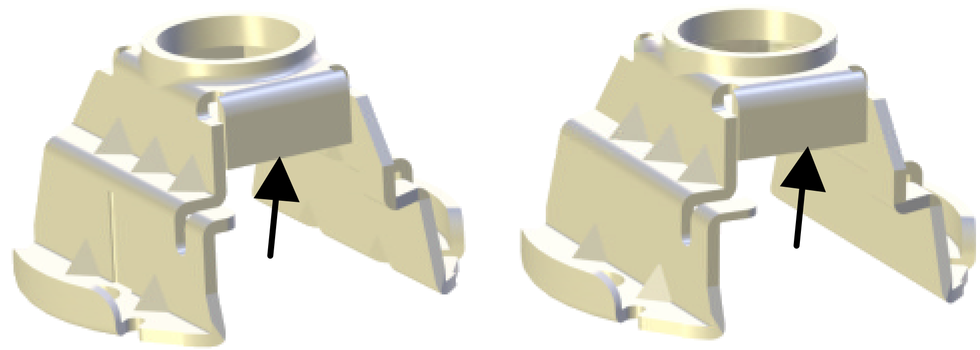


Taller Slider

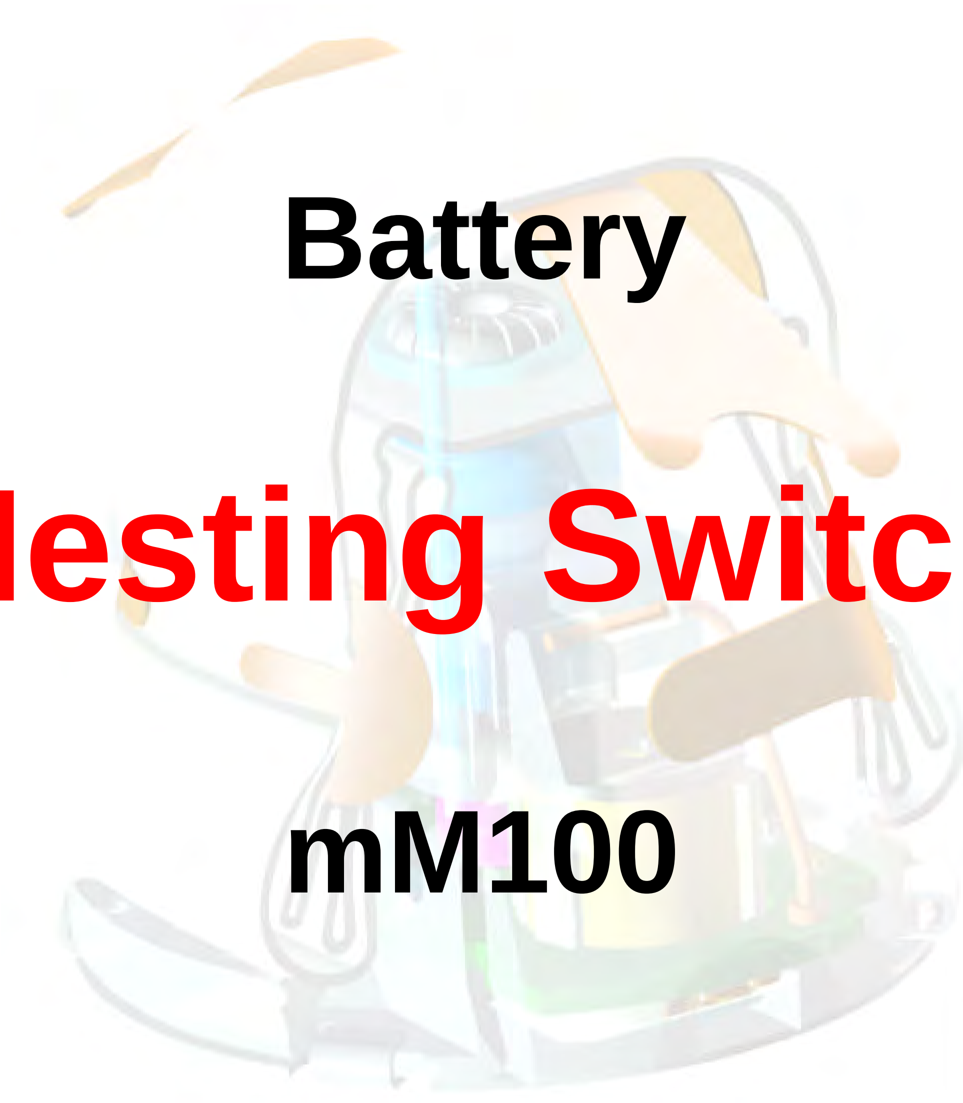




- Slider height increased to allow maximum room for Battery



- Tab on front of M234 Housing has been shortened



Battery

Nesting Switch

mM100

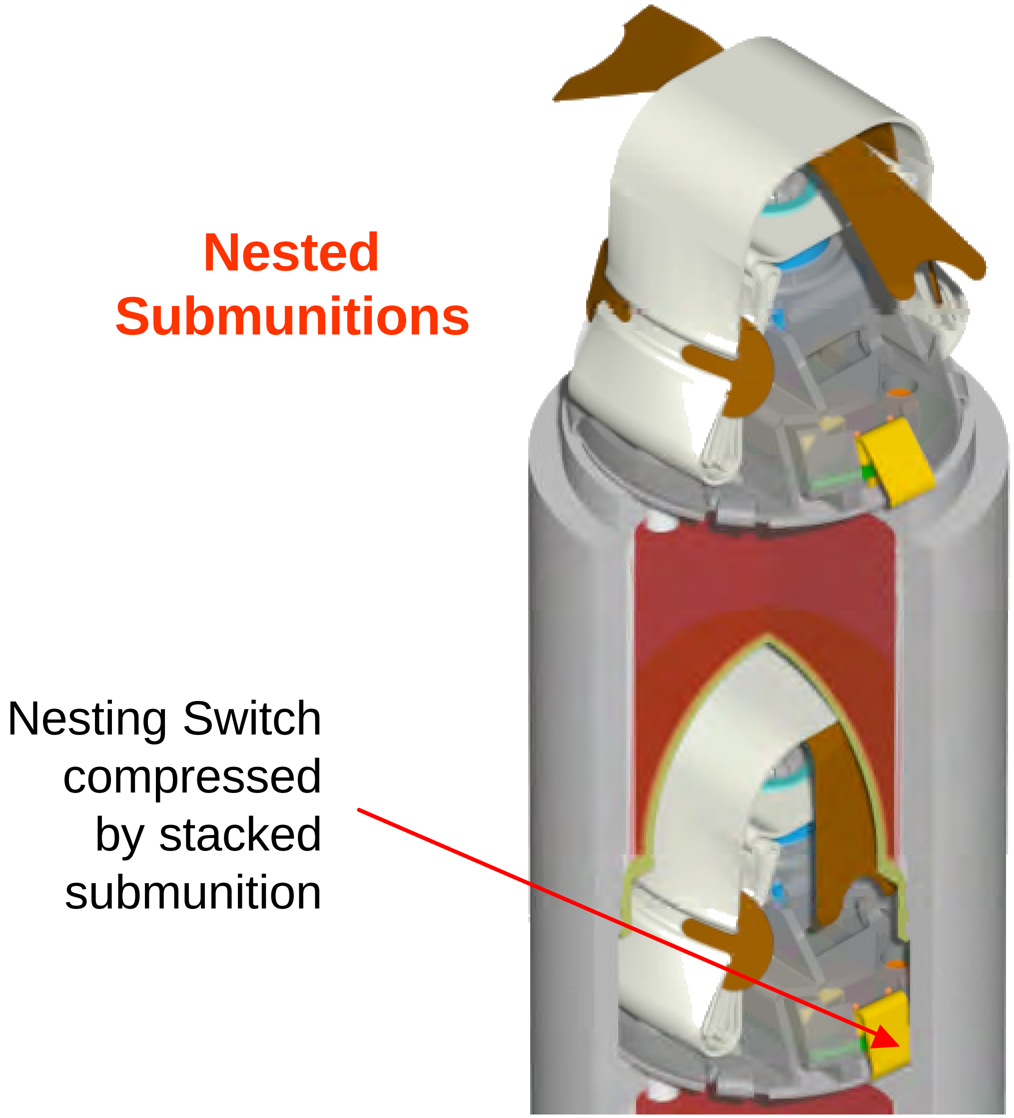
Nesting Switch

- **Description**
  - Replaces the function of the Shunt on the M234 SDF
    - Self-Destruct timer
    - Room needed for Antenna, Battery, & electronic components
  - Prox. Fuze Sensor off line until submunitions dispensed
    - Reduces power consumption until M80's dispensed
  - Closed while the submunitions are nested in the payload
- **Allows Self-Destruct time to be reduced from 3 minutes to 60 seconds - desired by Marines**

Nesting Switch

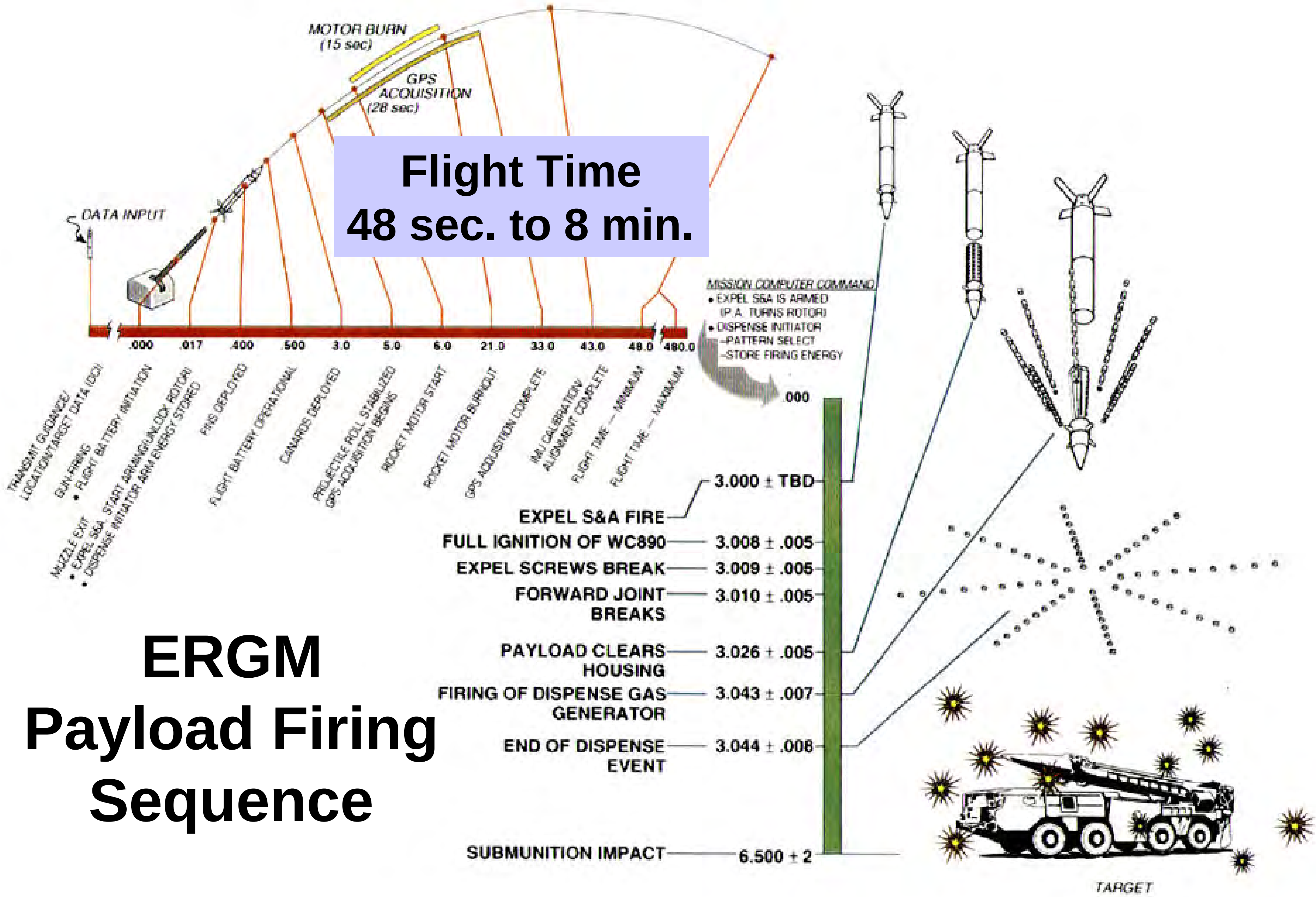
Nesting of grenades closes switch contacts

- **Fault Tree Analysis**
  - Shows the use of the Nesting Switch to be as safe as the Shunt
- **Safety Analysis**
  - Lone Star Army Ammunition Plant Concurs



ERGM Payload Firing Sequence

Flight Time
48 sec. to 8 min.

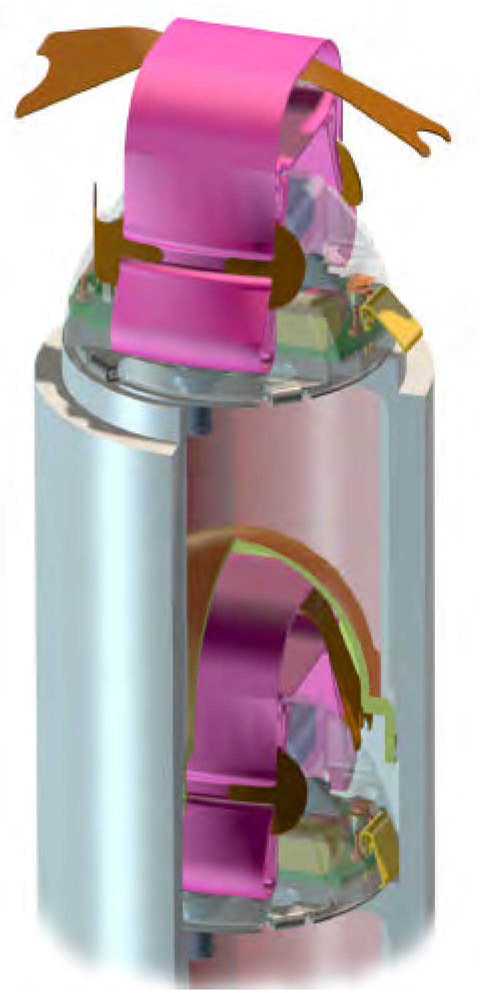


Accident Scenario

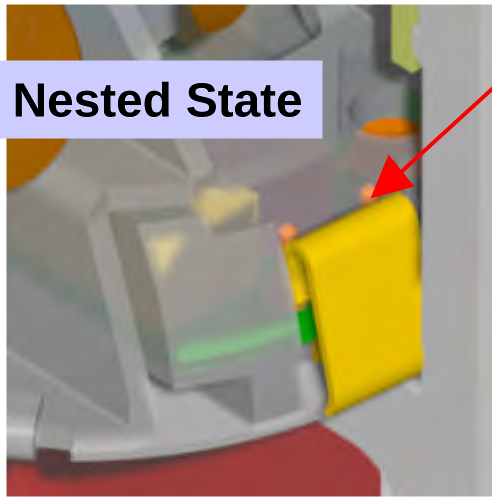
- **Assumption:**
  - The accident in some way has activated the Battery and the electronics are powered up
    - Drop, Accidental Expulsion
- **Safety Logic:**
  - The Signal Processor IC will compare the Nesting Switch condition and Separation Timer (Battery activation time)
    - If the Nesting Switch is opened within 30 seconds of Battery activation the Prox. Fuze will safe itself
    - If the Nesting Switch is closed in the nested state and the Battery has been activated for 10 minutes the Prox. Fuze will safe itself

*** Point Detonate Safety Issue still a concern**

Nesting Switch Concept #1

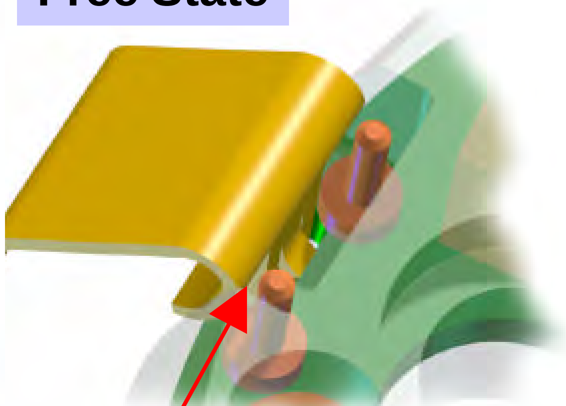


Nested State

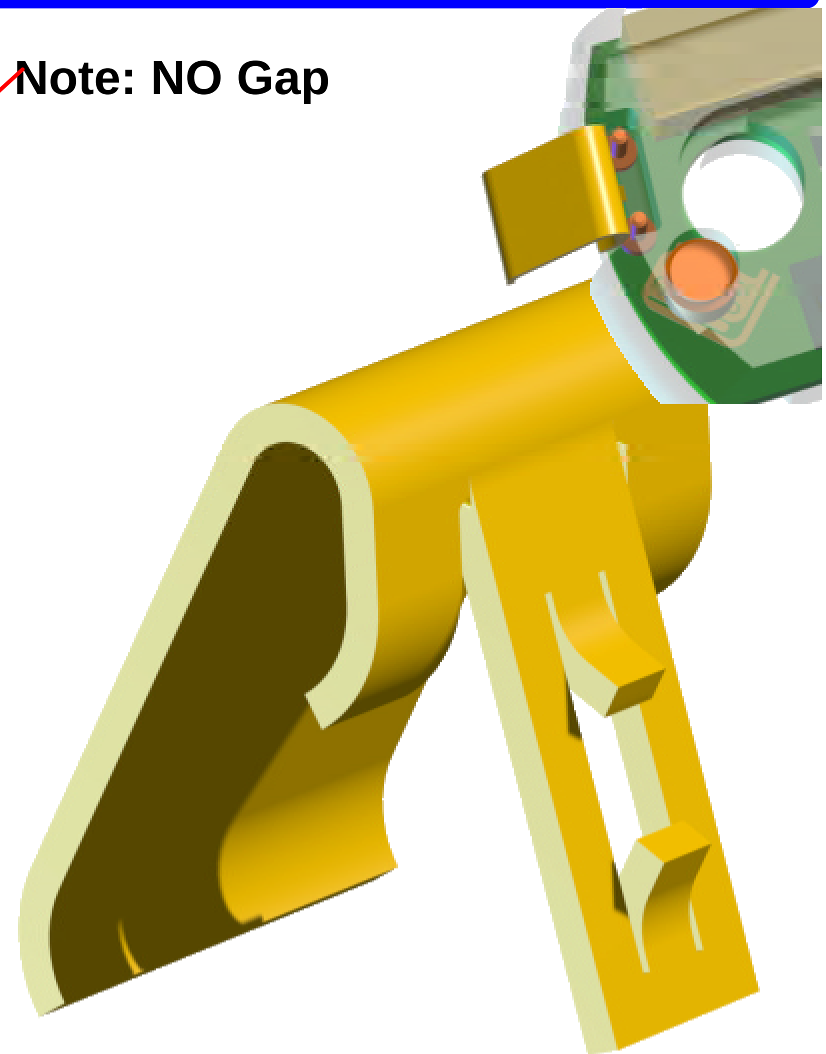


Note: NO Gap

Free State

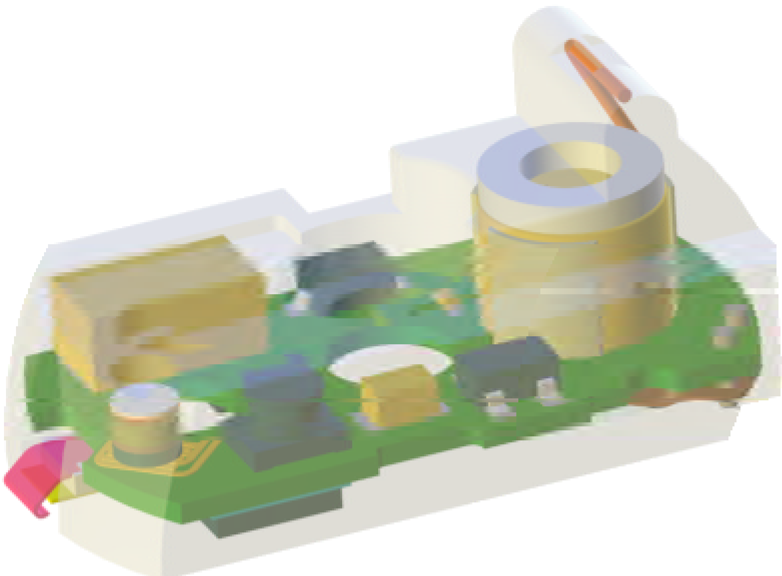


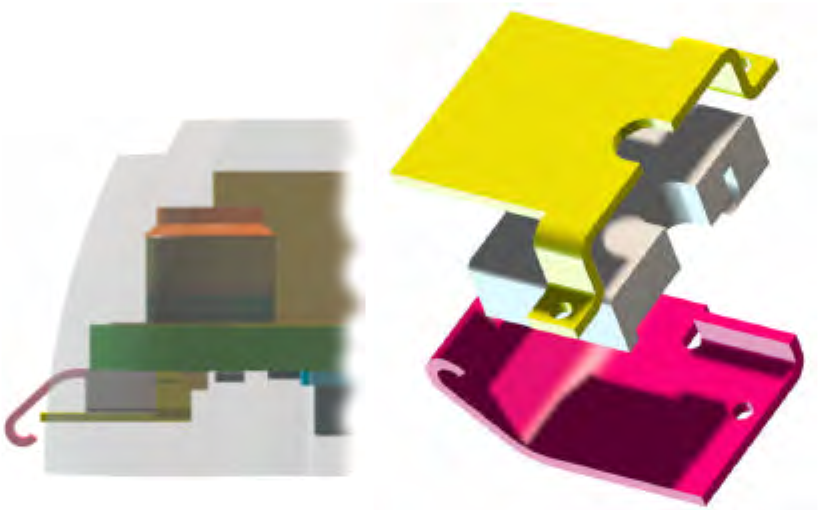
Note: Gap

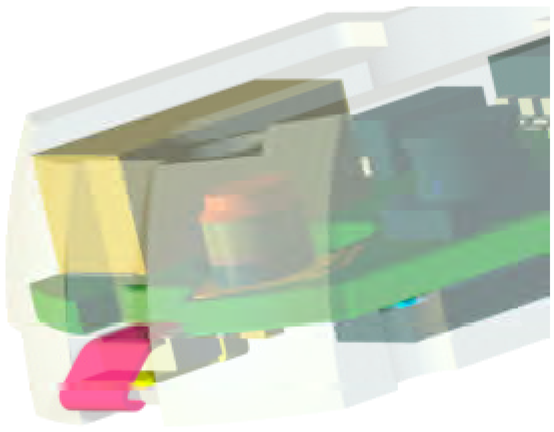


Nesting Switch Concept #2

- The PWB is molded to form the Slider
- The two Nest Switch leaves are molded together
- Then soldered to the Slider Sub-Assembly





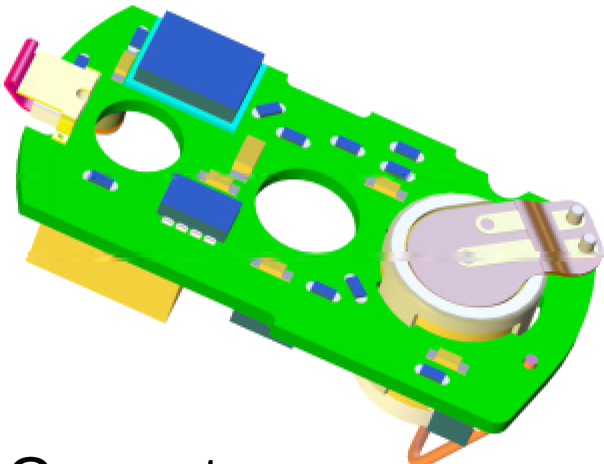


Battery

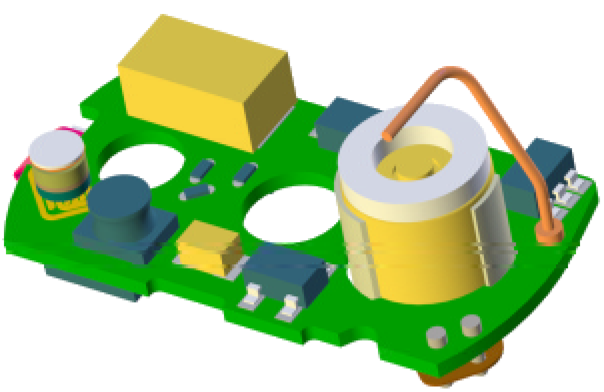
Nesting Switch

mM100

EED vs. mM100



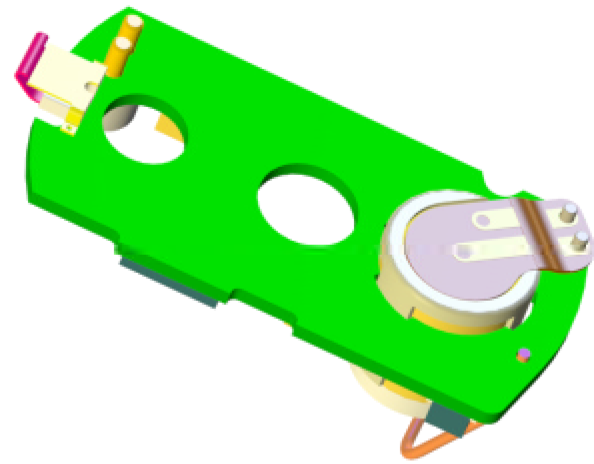
Current
M234 EED
Version



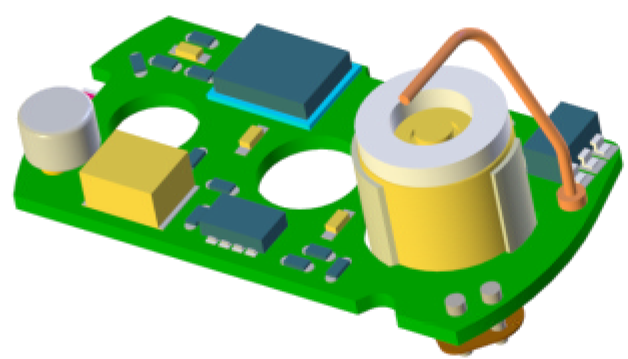
mM100 design offers

- **Reduced component count**
- **Reduced component sizes**
- **Reduced testing**
- **Single sided PWB**
- **Reduced PWB costs**
- **Increase reliability**

- **No impact on battery**
- **Either Nesting Switch concept**



mM100
Version



Summary

- **Teamwork**
  - Government and Contractor
  - Battery, Electronics, and Mechanical Packaging Teams

KDI Precision Products, Inc.

An ISO 9001 Registered Company

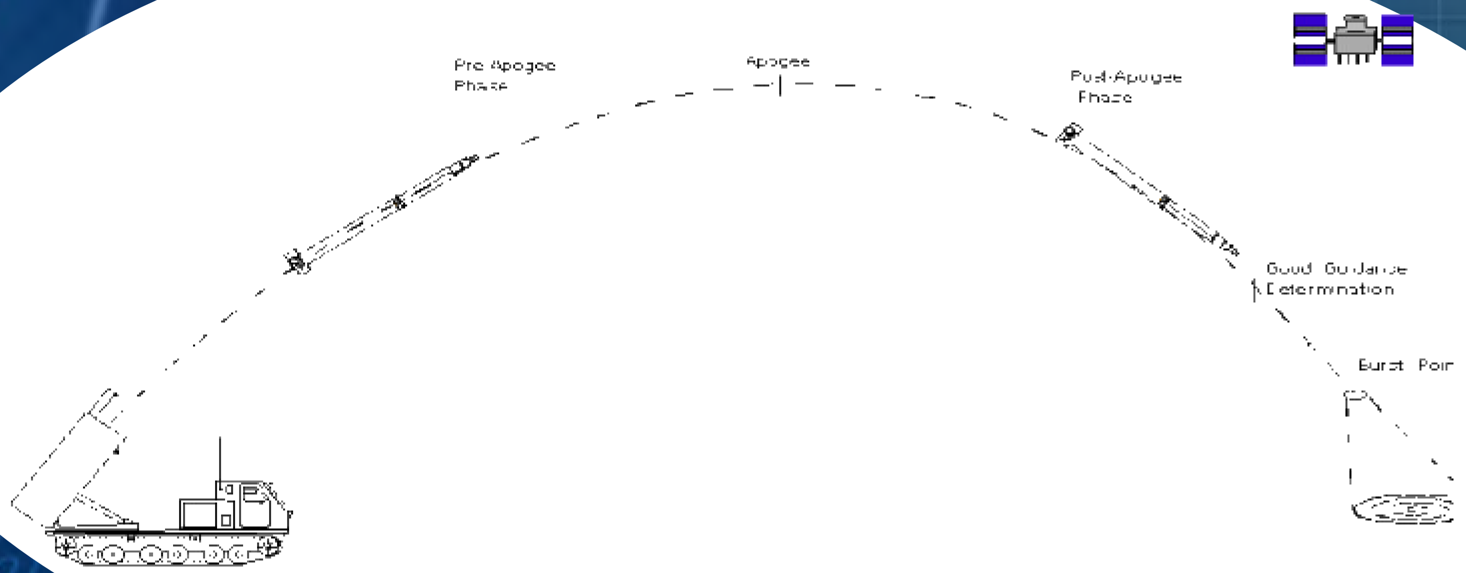
Presented by: Mr Ted Lewis

GUIDED MLRS USA AND FOREIGN PARTNERS

KDI PROGRAM TEAM

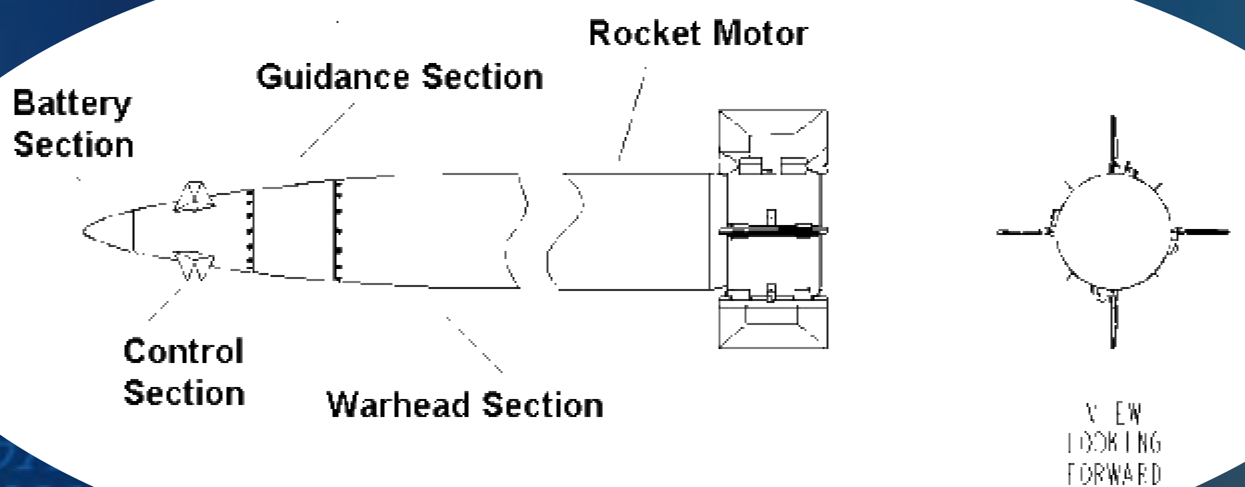
- Mike Buckhanan - Program Manager
- Ted Lewis - Electrical Project Engineer
- Cory Hatch - Electrical Engineer
- Tony Zucker - Mechanical Project Engineer
- Mike Sowder - Test Equipment Electrical Engineer
- Steve Gemperline - Quality Engineer, CQE
- Bob Garrett - Reliability Engineer
- Tom Moore - Manufacturing Engineer
- Bob Butts - Configuration Management

GMLRS OPERATION

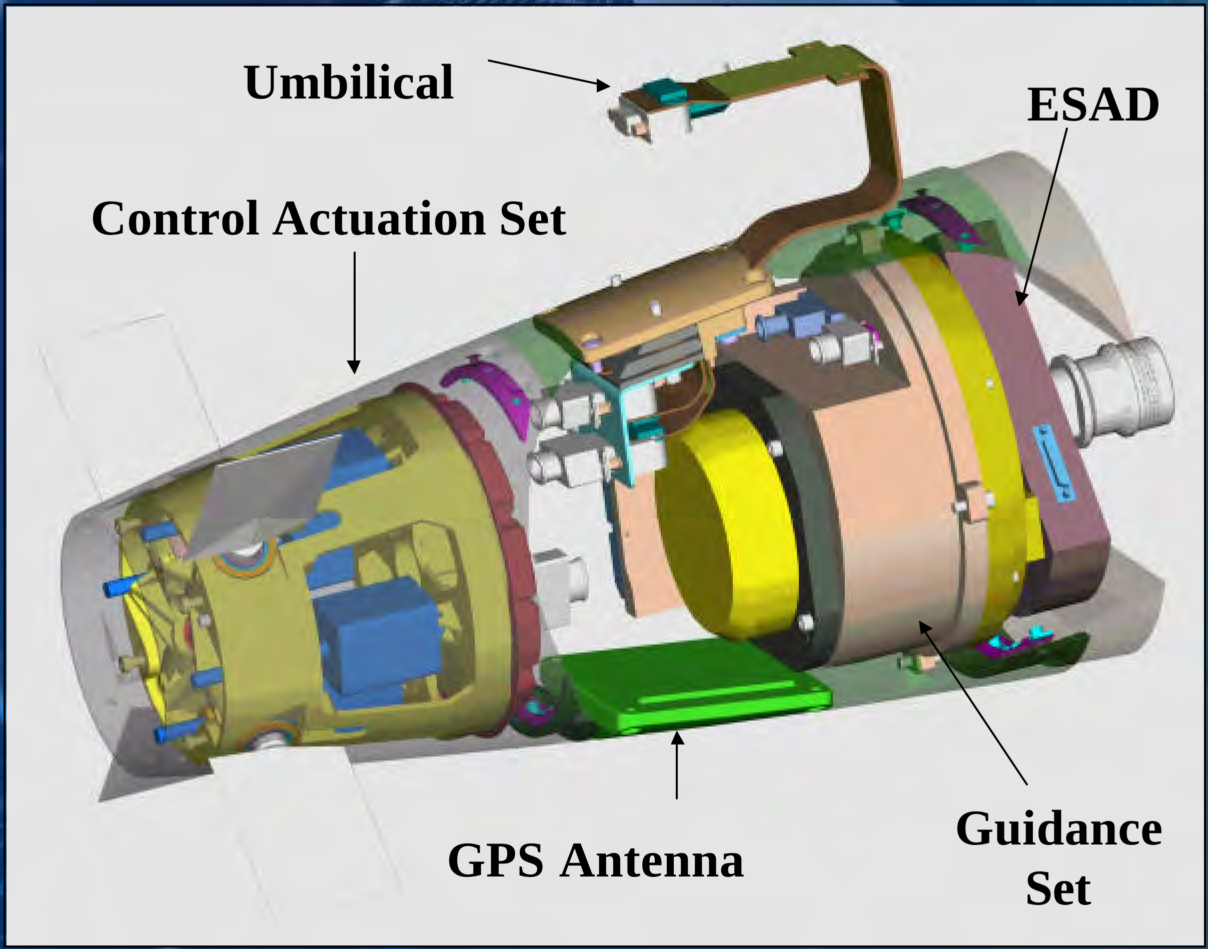


GMLRS ROCKET

- The GMLRS Rocket Is Nominally a Ballistic Round
- The Maximum Off-axis Shot Is 4° Degrees
- The Canards Are Used Only for Trimming the Trajectory During the Flight



GUIDANCE AND CONTROL SECTION



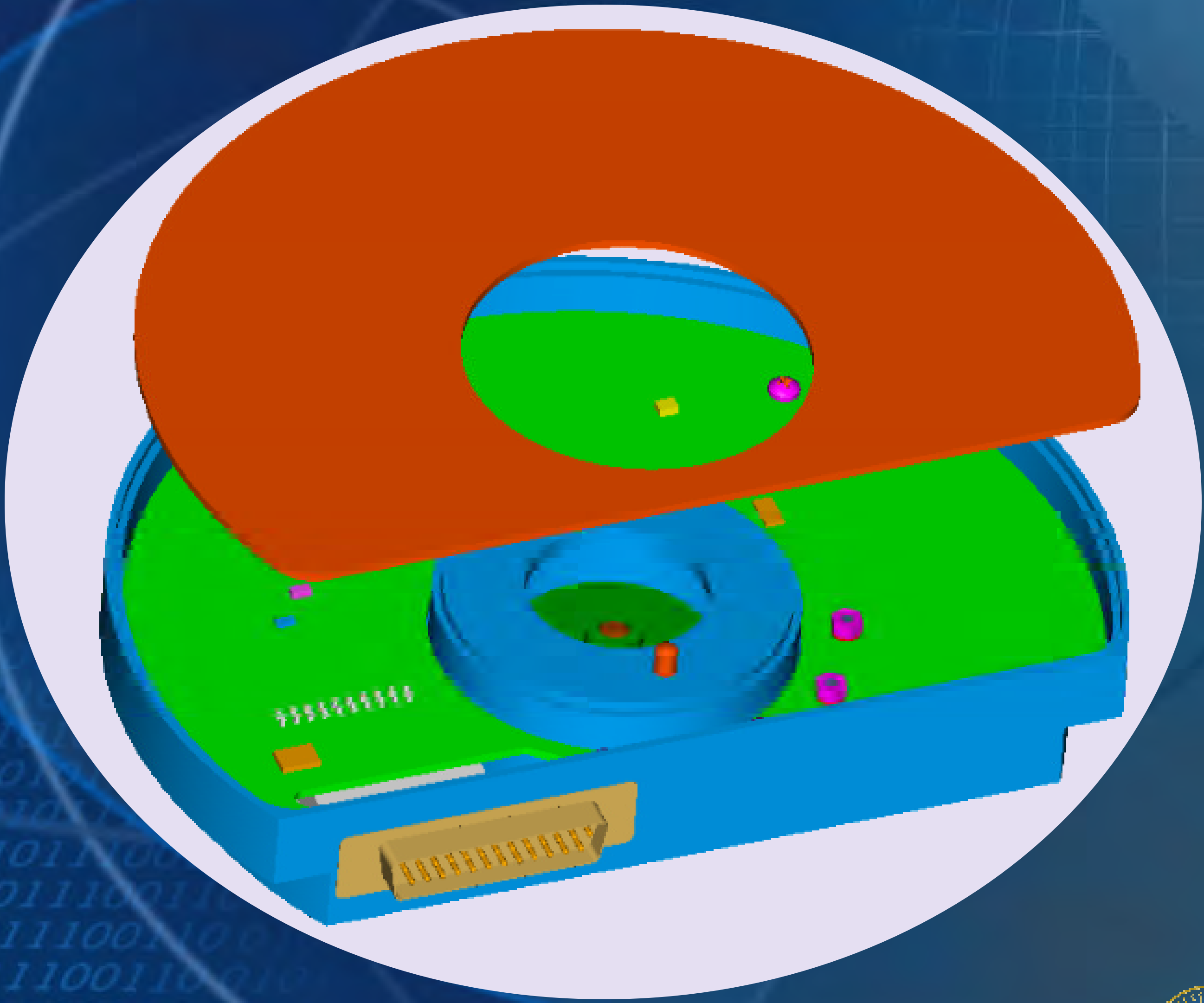
HOUSING

- Material: 304L Stainless Steel
- Function
  - Interfaces to LEEFI Adapter Assembly
  - Interfaces With Rocket
  - Alignment Feature Incorporated
  - Hermetic Environment
  - Supports Printed Wiring Board (PWB)

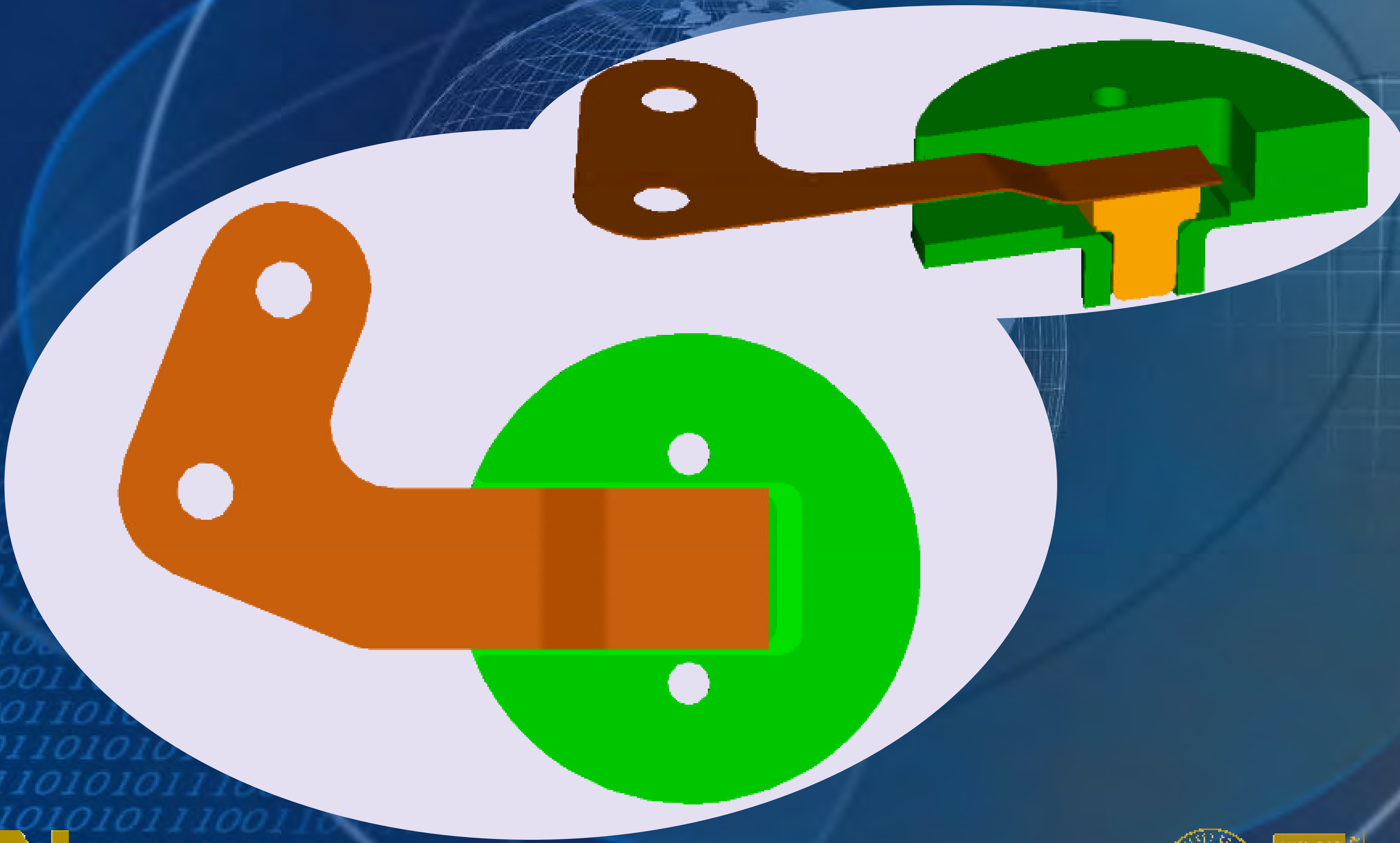
SEALING

- The ESAD Will Be Hermetically Sealed and Tested to Meet a Leak Rate of 1 X 10-6 cc/sec He/Mass Spectrometer at 1 Atmosphere Pressure Differential
- Laser Welding Will Be Used to Seal the Housing, Similar to the Other Qualified Programs at KDI
- The GMLRS ESAD Will Be Back-filled With Nitrogen With A Trace Of Helium Through A Fill Plug

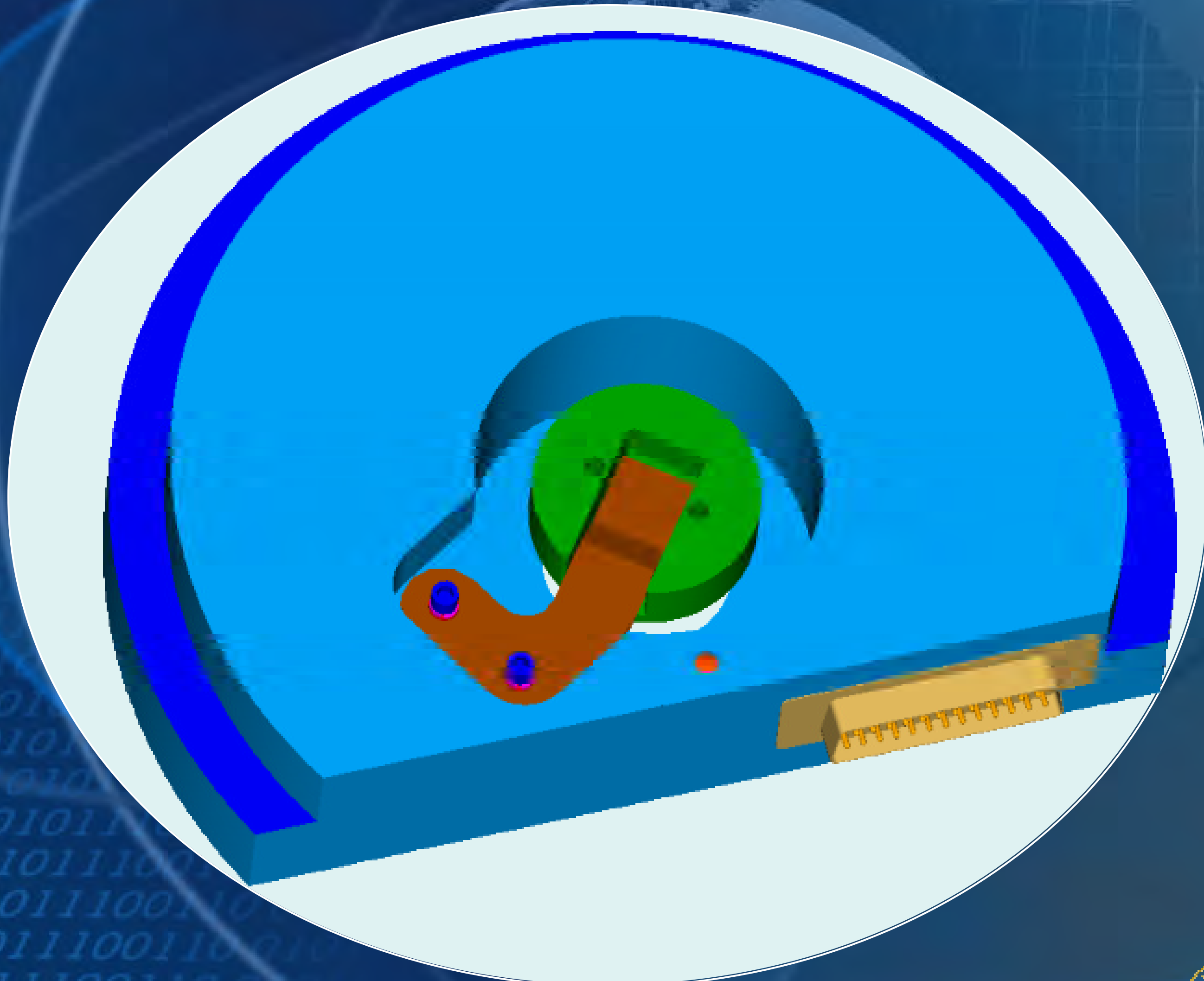
EXPLODED VIEW



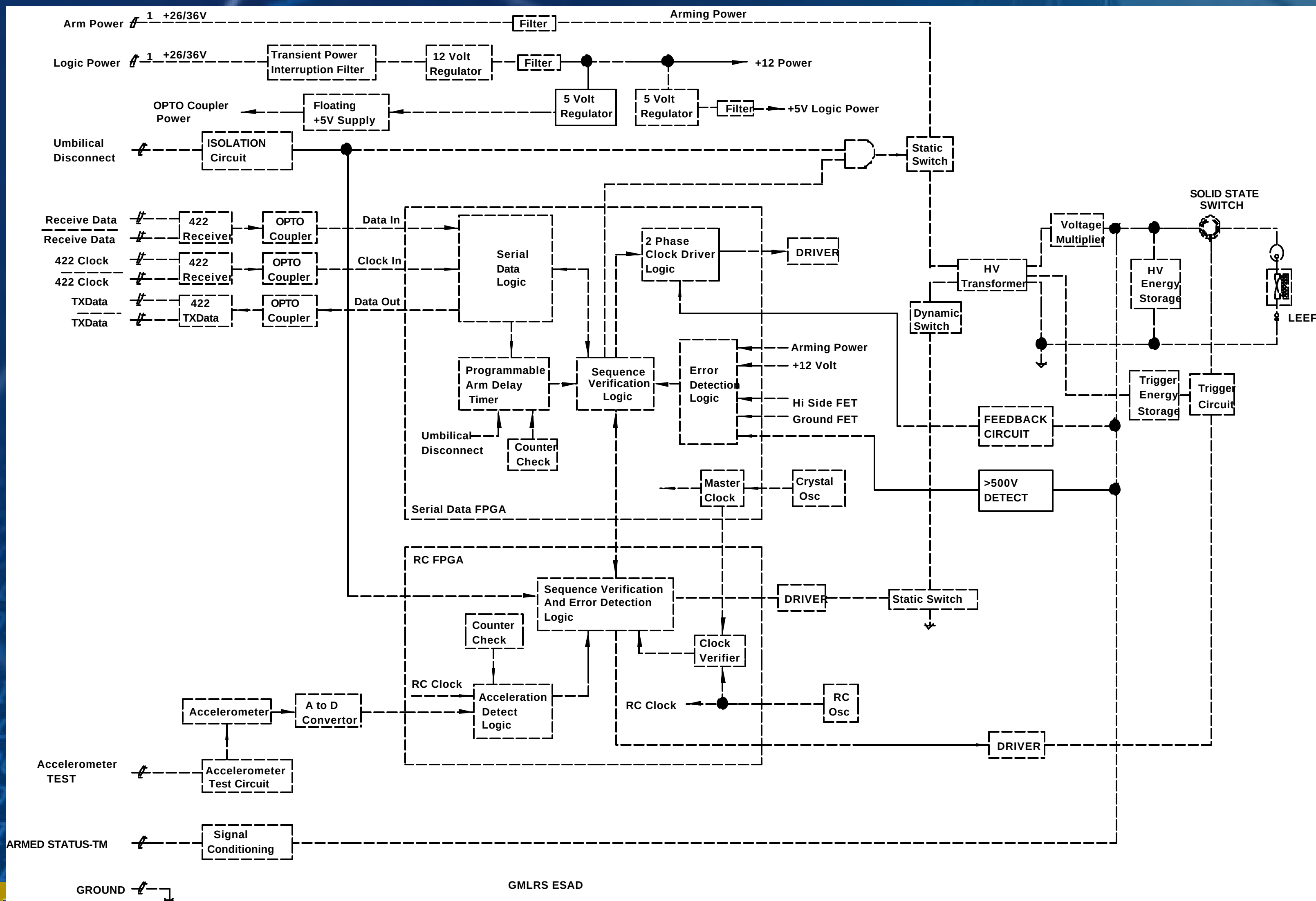
LEEFI ADAPTER ASSEMBLY



GMLRS ESAD WITH LEEFI ADAPTER ASSEMBLY



DETAILED BLOCK DIAGRAM



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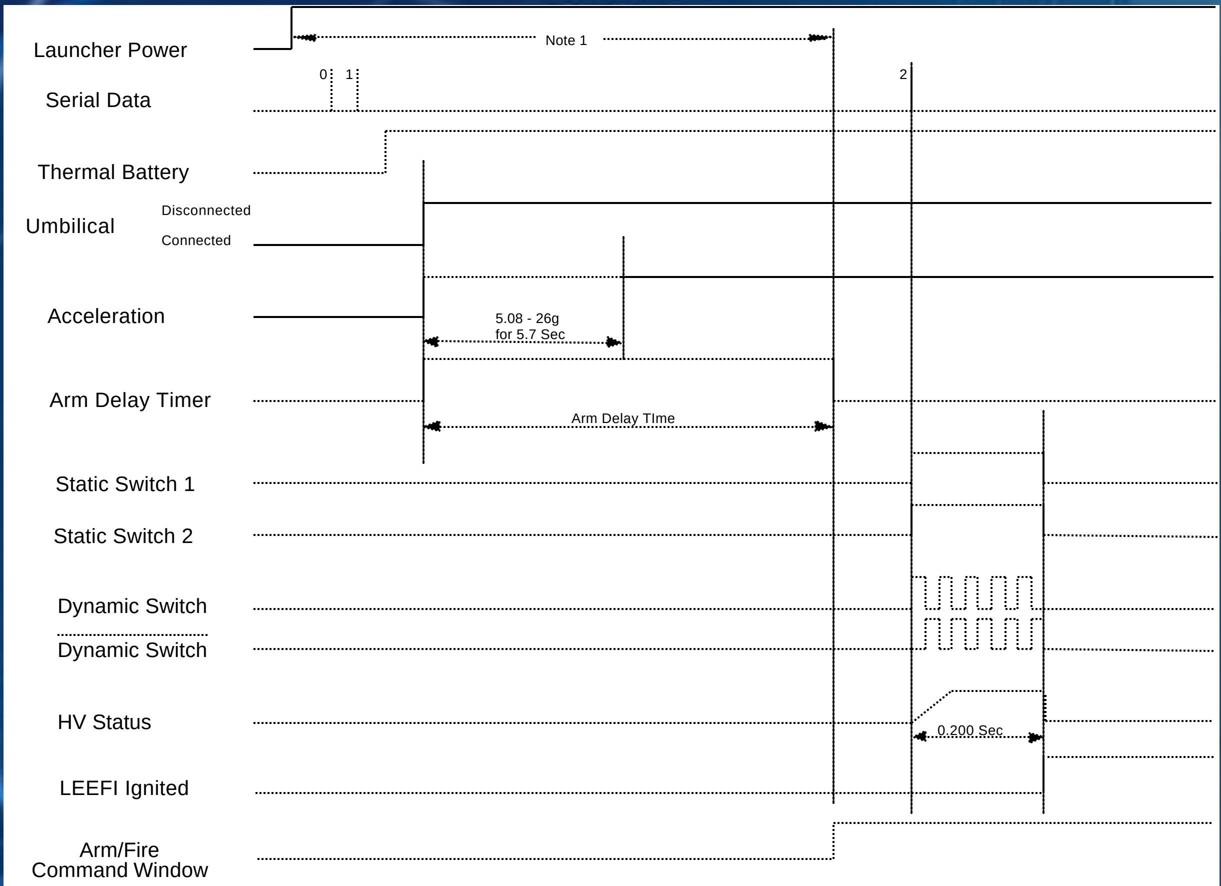
TIMING DIAGRAM



Serial Commands

0 - Report Current Status Command (Sent Periodically Throughout Flight)

1 - Load Arm Delay Time Command

2 - Arm/Fire Warhead Command

Note 1: Arm/Fire Warhead Commands Are Rejected Until Arm Delay Timer Expires

SERIAL INTERFACE

- 442 Drivers/Receivers
- SDLC Message Formats

Guidance to ESAD Message

48 BITS

- 8 BIT Start Word
- 8 BIT Command Word
- 8 BIT Delay Time
- 16 BIT CRC
- 8 BIT Stop Word

ESAD to Guidance Message

64 BITS

- 8 BIT Start Word
- 20 BIT Command Word
- 4 BIT Delay Time
- 8 BIT Timer Status
- 16 BIT CRC
- 8 BIT Stop Word

ACCELERATION PROCESSING

- Motorola MMA1201P Analog Accelerometer
  - ± 40g Capacitive, Micromachined Accelerometer
  - Output Sensitivity = 50 ± 2.5 mV/g
- Accelerometer Readings Are Taken Every 340µS
- Accelerometer Output Level Checked During BIT
- Accelerometer Output Level "Nulled" When Battery Power is Applied
- Specification Requirements:
  - 1st Motion = 5.08g for 6 msec Within 0.5s From Umbilical Disconnect
  - Safe Separation = 5.08g for 5.7 ± 0.1 Seconds

LEEFI ASSEMBLY

- Designed in Unison by China Lake, Reynolds Systems and Silicon Designs
- The LEEFI Has Been Qualified by China Lake IAW MIL-STD-331, Test G1
- Specific Tests Designed to Demonstrate the Initiator Meets a Reliability of 0.99 at a 95% Confidence Level Were Performed

MCT SEMICONDUCTOR DISCHARGE SWITCH

- N-Type MOS-Controlled Thyristor
- 1400 Volt
- 4ka Surge Current
- Silicon Power Corporation
- Tested in KDI IRAD Program
  - > 20,000 Discharges

PROGRAM STATUS / SCHEDULE

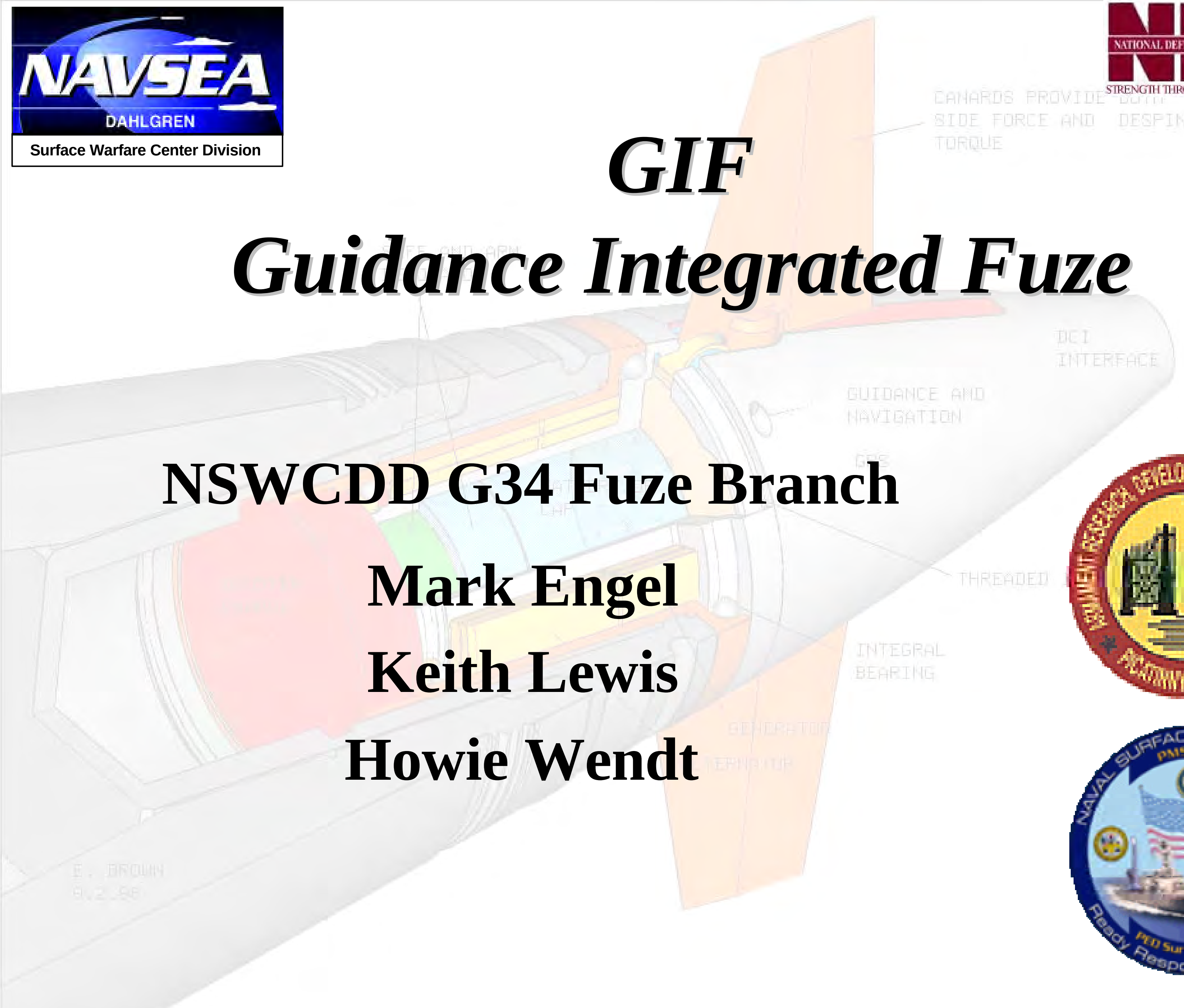
- Initial AFSRB Presentation - Completed 19 Dec 2000
- PDR - Completed 1-2 Feb 2001
- Engineering Tests - 15 Nov 2000 To 31 Mar 2001
- CDR - 27-28 Mar 2001
- Qualification - 30 May 2001 To 17 Jul 2001
- Flight Hardware Delivery 1 June -28 Sept 2001

QUALIFICATION TESTING

- Twenty ESADS Will Be Subjected to Qualification Testing
- The Qualification Test Environments Will Consist Of:
  - Thermal Shock
  - Tactical Vibration
  - Launch Shock
  - High Temperature Operation
  - Low Temperature Operation
  - Acoustic Noise and Flight Simulation
- Electromagnetic Environment

Surface Warfare Center Division

GIF
Guidance Integrated Fuze



NSWCDD G34 Fuze Branch

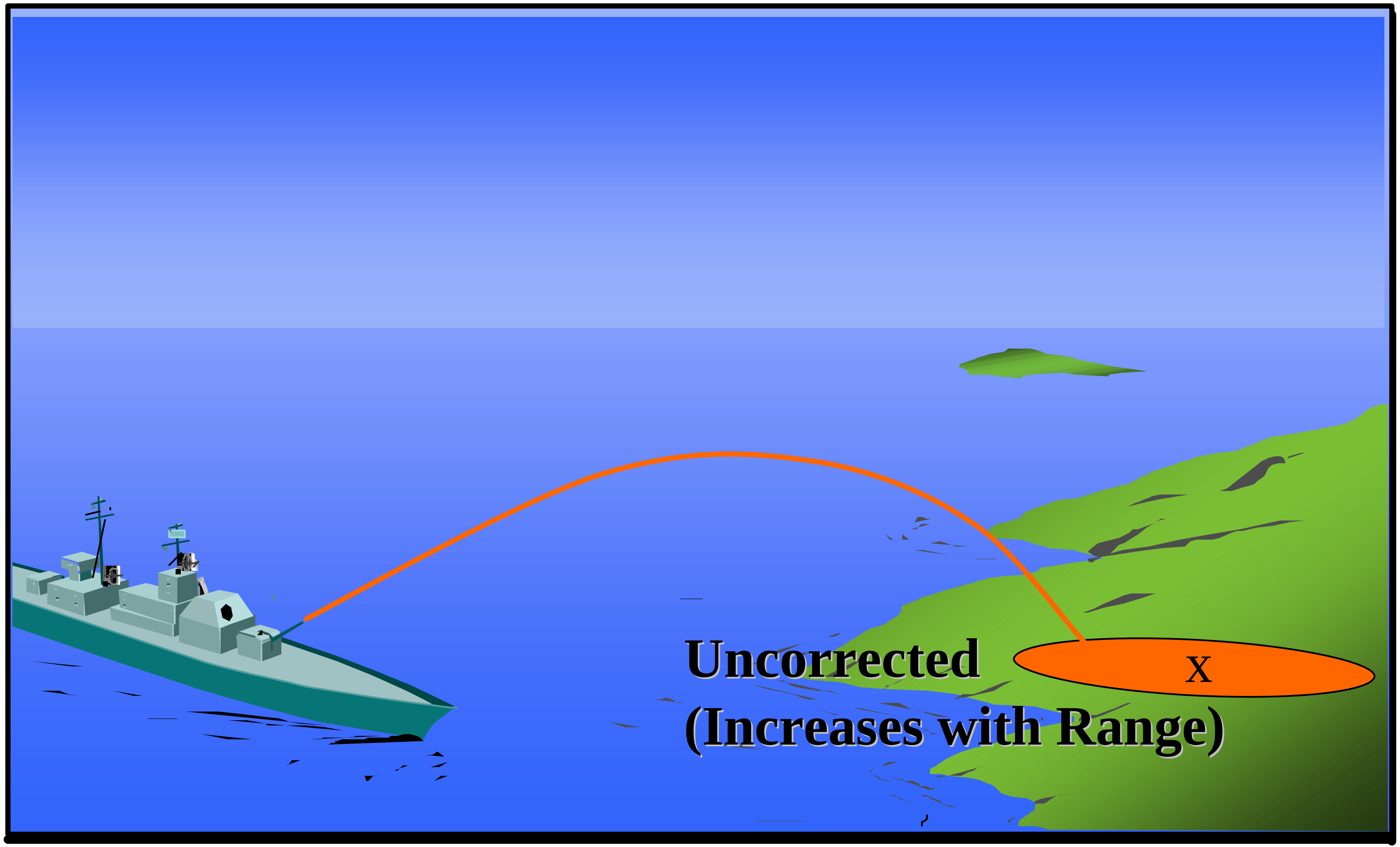
Mark Engel

Keith Lewis

Howie Wendt

NAVSEA DAHLGREN
Surface Warfare Center Division

Inaccuracy

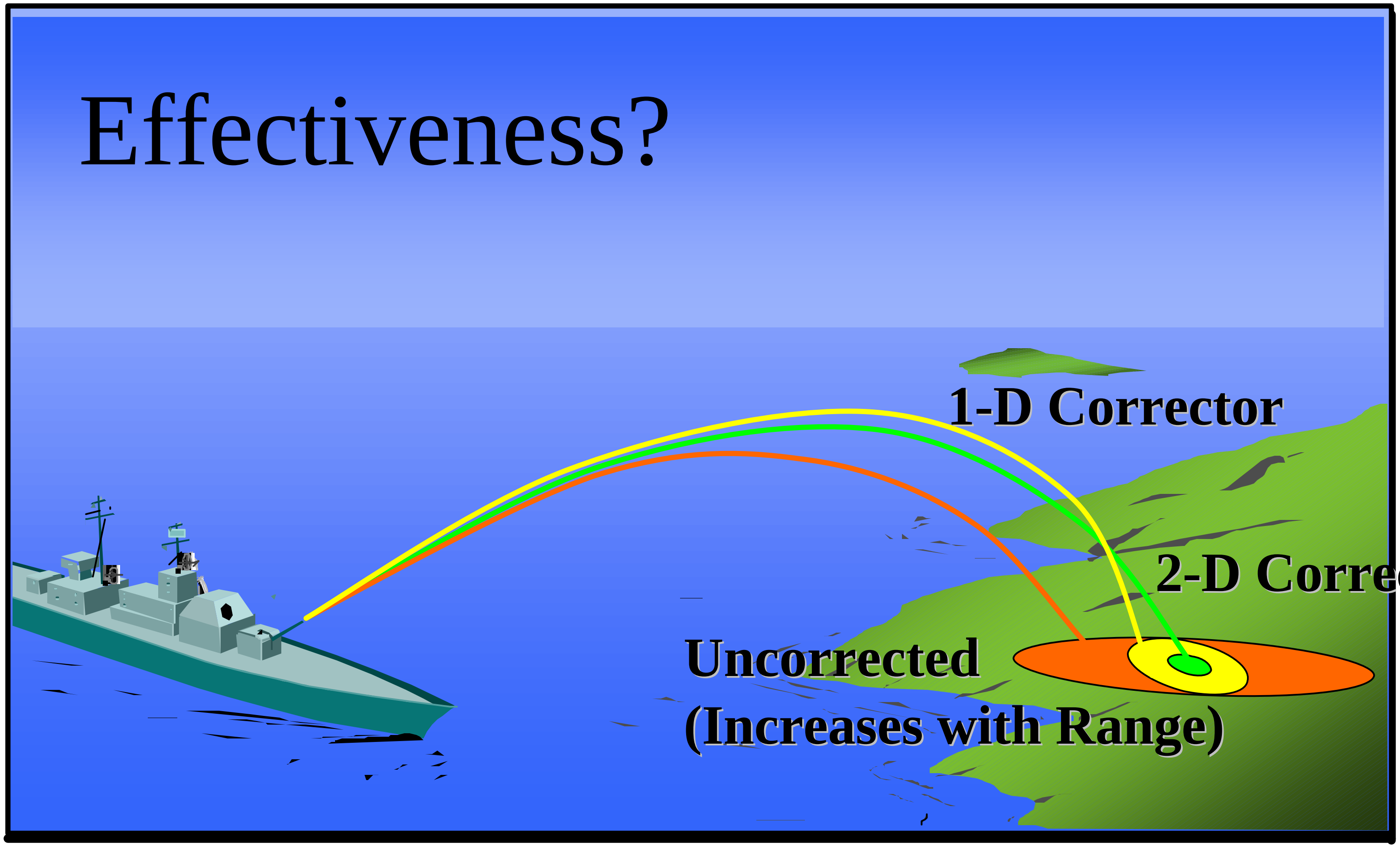


Background

- Why? Improved Accuracy
- Who?
  - US Army, US Navy, Foreign Services
  - Industry
- Other Guided Projectiles:
  - CMATD
  - TCM
  - STAR
  - ERGM & LCGEU
  - XM-982
  - ANSR
  - Barrage

Surface Warfare Center Division

1-D vs. 2-D



Approach

- 1-D vs. 2-D? Team Star examining 1-D
- Can Canards Give Acceptable Control Authority?
- Will it Fit?

Control Authority?

ARDEC (Picatinny) Analyzing Trajectories with Canards

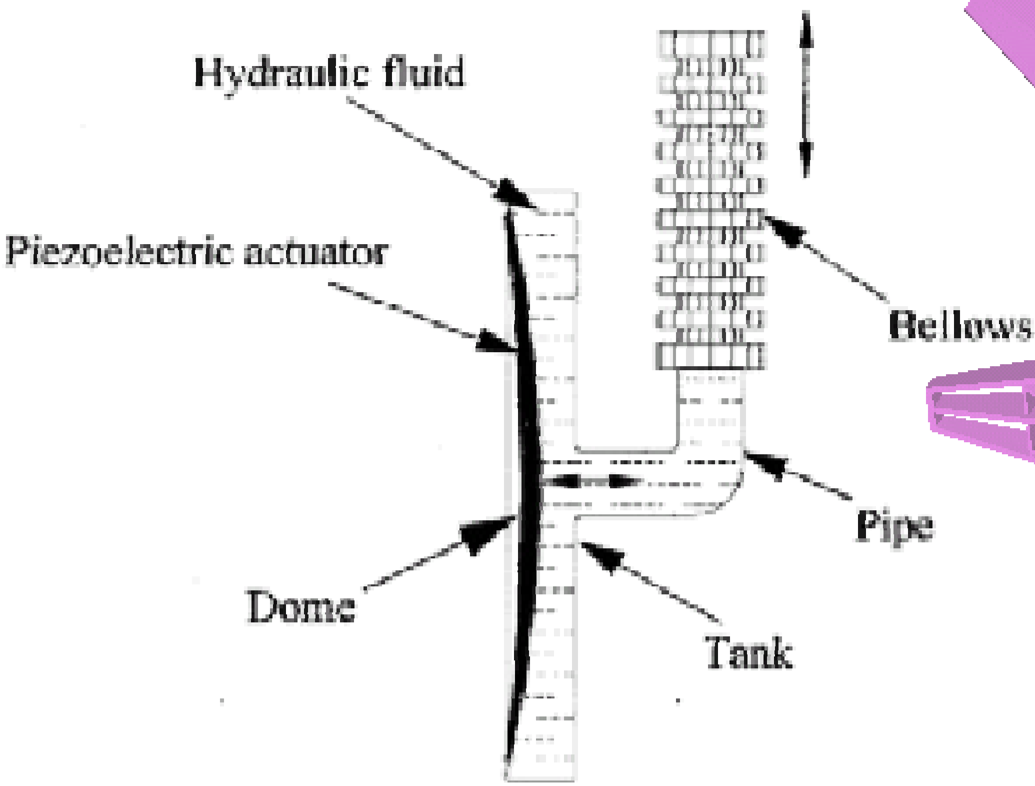
- ✓ Incorporated CMATD Aero into 7-DOF
- ✓ Compared Sample Runs with Draper 7-DOF

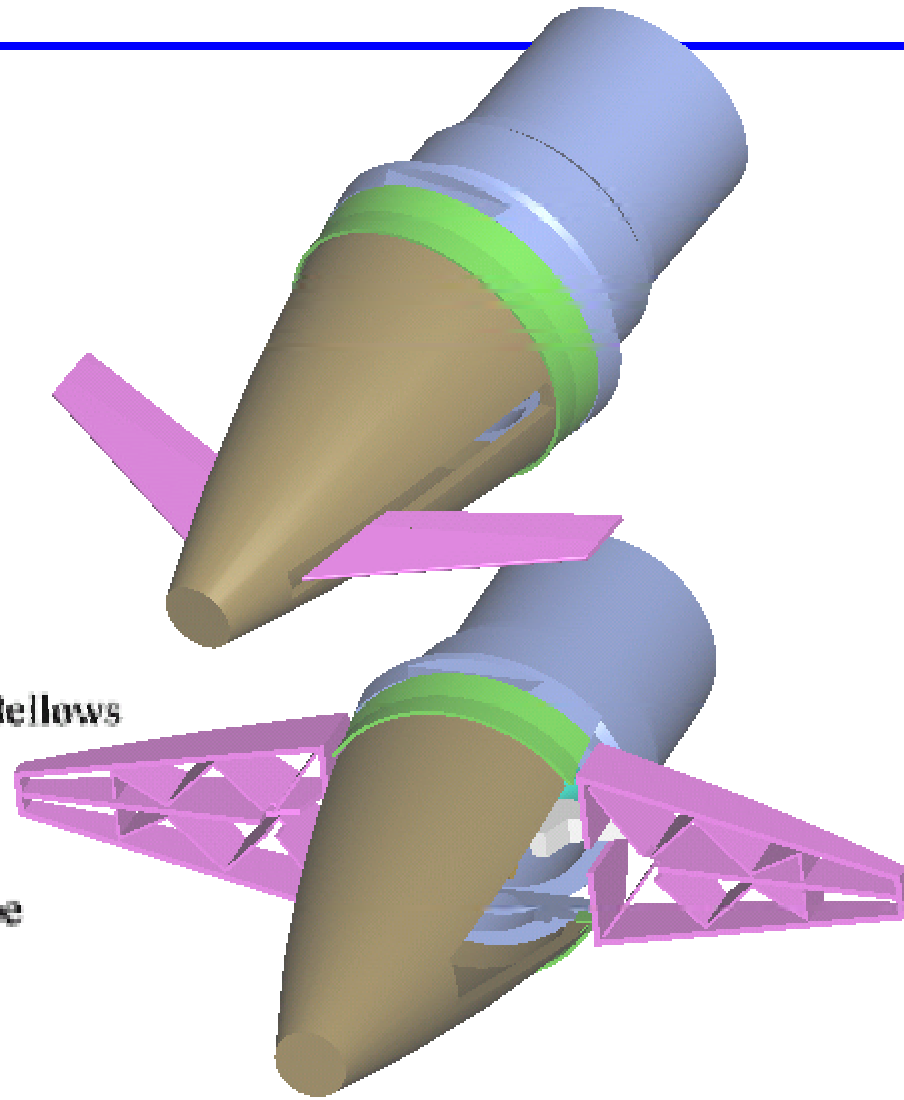
- ! Implementing Closed-Loop CMATD Guidance Algorithms

- ➢ Simulate CMATD Flights for Check
- ➢ Incorporate GIF Canards
- ➢ Simulate GIF Flight for Maximum Control Authority

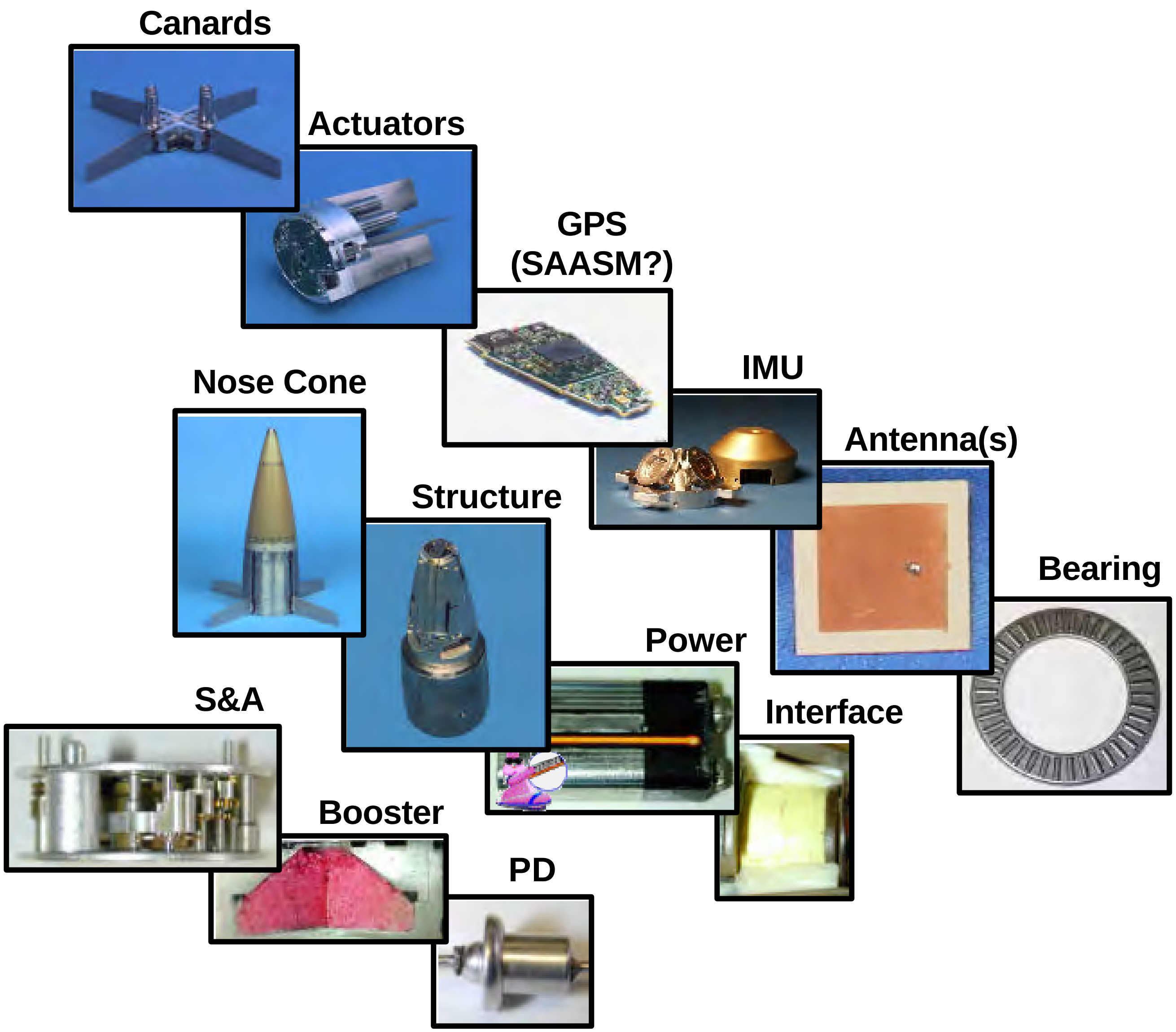
First Step - Canards

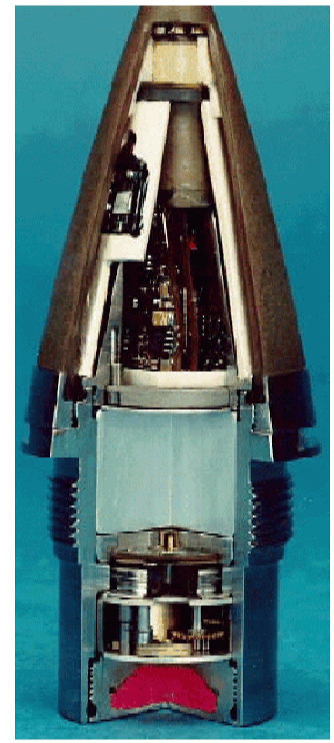
- Canards
- Actuators





Fit It In 9 Cubic Inches





NATO Standard Fuze

NAVSEA DAHLGREN
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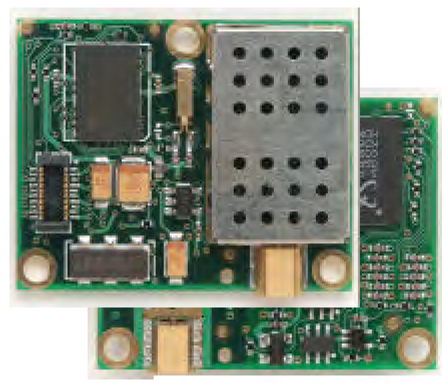
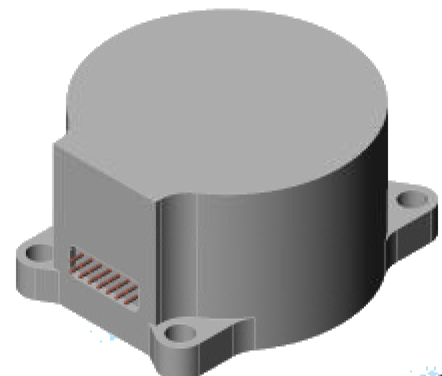
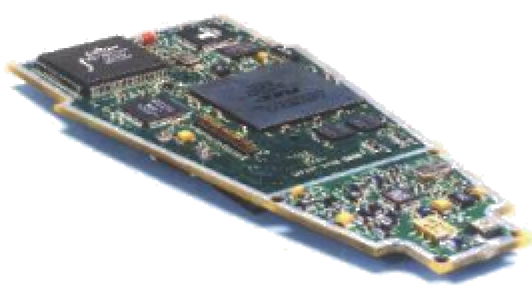
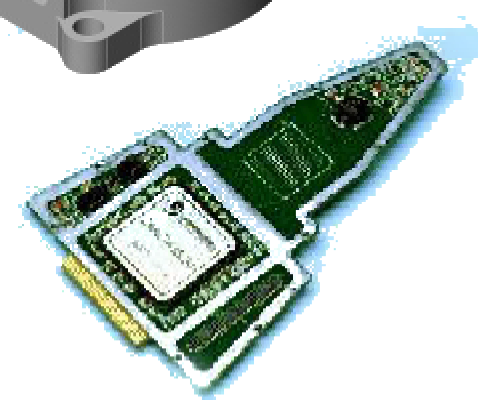
GPS/INS

- Looking for Existing Technology
- Looking for Future Technology



Other Issues

- Battery vs. Generator
- MEMS S&A (but micro detonators?)
- Rolling Canards
- Single vs. Multiple Antennas
- Power Before Flight

Surface Warfare Center Division

Near Term Plan

- Trajectories to Determine Control Authority
- Realistic Volume Allocation
- Options for Power and Rolling Canards
- Collect Data on GPS, INS, Actuators

NAVSEA DAHLGREN

BULOVA TECHNOLOGIES LLC

MK 432 ELECTRONIC TIME FUZE

A New Fuze for the US Navy

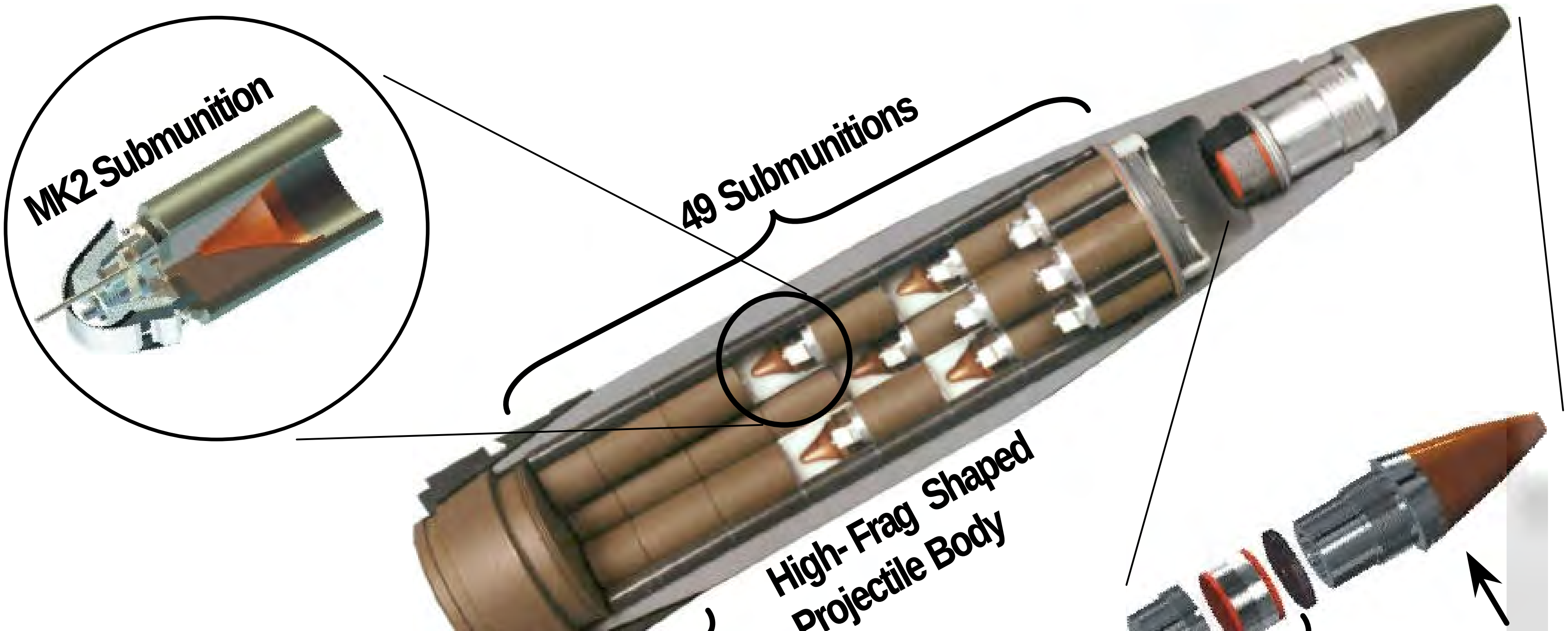
Chad Finch, G34 Fuze Branch

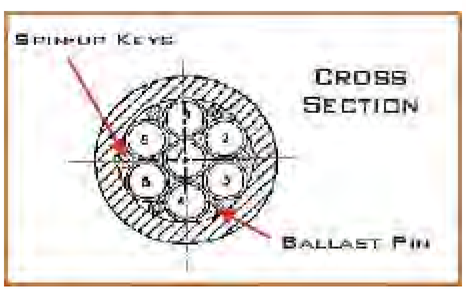
Dave Mengel, Bulova Tech

TACOM

Mobility and Firepower for America's Army

Navy 5" Cargo Projectile
EX 172 HE-ICM



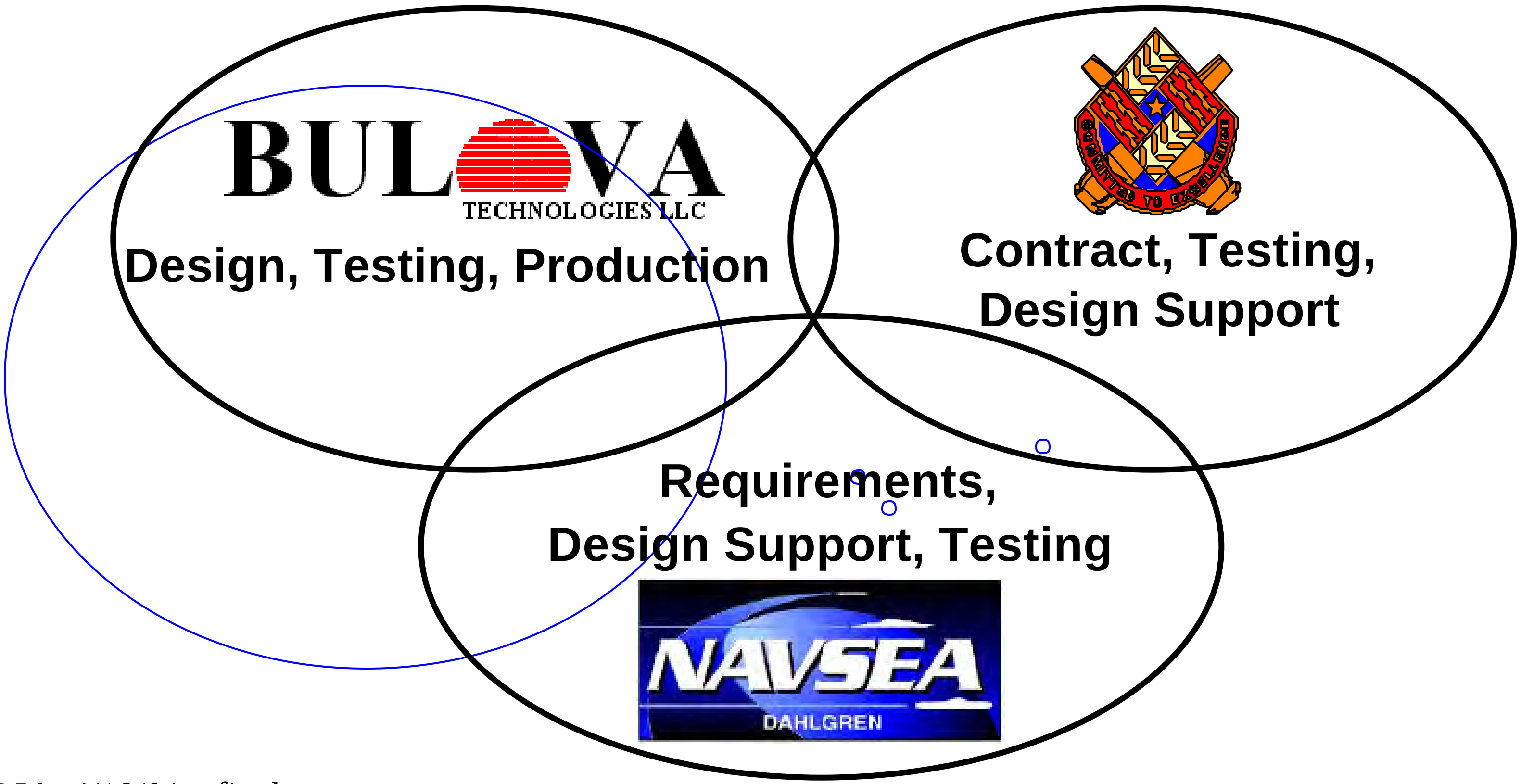


Fuze Alternatives

	MK 429 MFF	Simplified MK 429	Modified MOFA	Modified M762A1
Development Cost	None	$1,000,000+	$1,000,000+	$1,000,000+
Projectile Compatibility	Proven	Proven	TBD	Proven
Overhead Safety	Acceptable	Acceptable	TBD	Excellent
Unit Cost	High	Medium	Low	Lowest
Total Cost 14,600 Fuzes	High	High	Medium	Low

Team Approach

- **Take Advantage of M762A1 MCP in Process**
- **Amended Army's MCP Contract on May 2000**



Requirements

- **Three Major Changes to M762A1 Fuze:**
  - **Compatibility w/ Gun Weapon System**
    - **Inductive Set Changes**
  - **Battery Activation**
    - **From Activate on Set to Activate at Gun Launch**
  - **Targets**
    - **Increased Timer Precision**

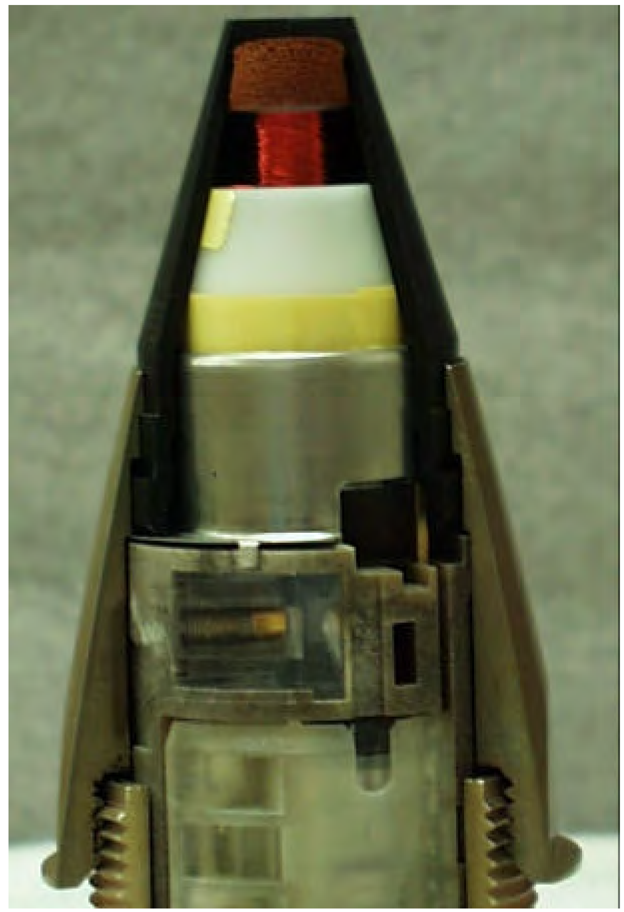
Inductive Set Changes

M762A1	MK 432
• PIAFS Setter	• MK 34 Setter
• 19 Bit Message	• 26 Bit Message
• Single Set Mode	• Continuous Set Mode
• Time Resolution ➢ 0.1 Second	• Time Resolution ➢ 0.01 Second

Inductive Set Changes

M762A1

MK 432

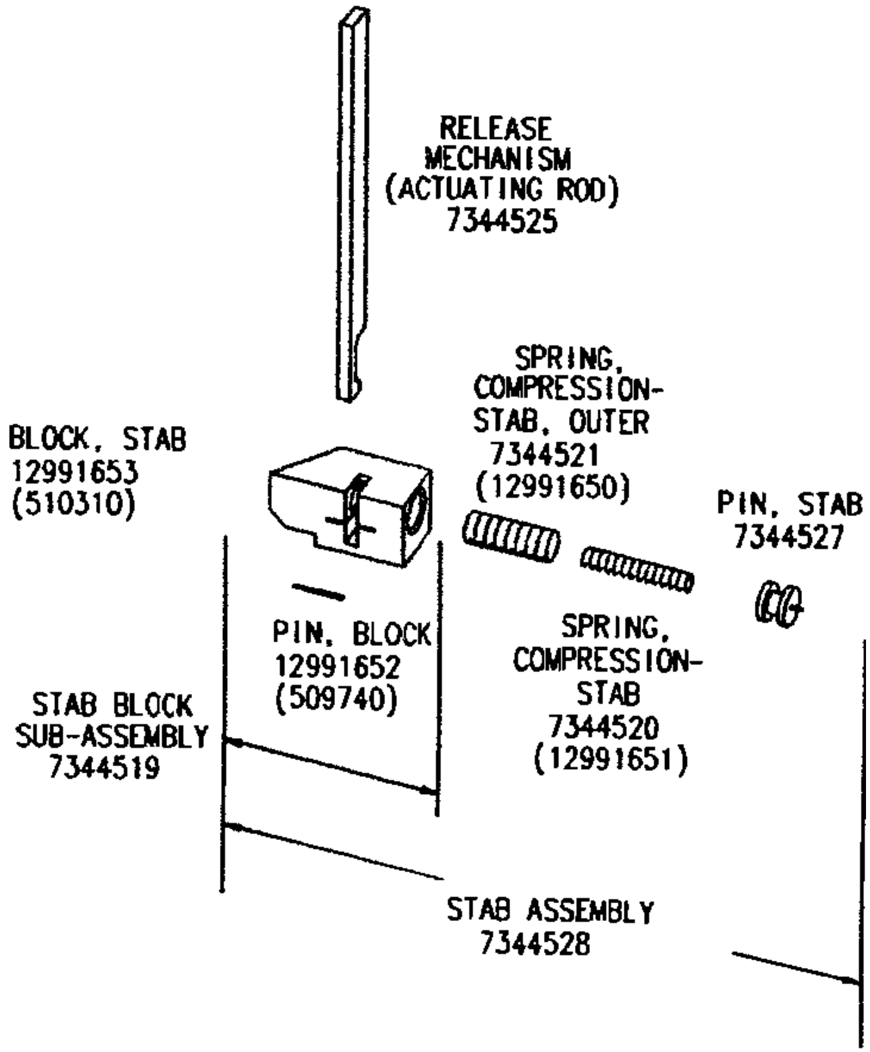


Battery Activation

- **M762A1**
  - ➢ **Activation on Set (Manual or Inductive)**
- **MK 432**
  - ➢ **Activation at Gun Launch Required**
  - ➢ **Redundant Activation Methods:**
    - **Electrical Activation**
      - **Spin Switch Closure Initiates Battery Primer**
    - **Mechanical Activation**

Battery Activation

- **Mechanical Activation**
  - ➢ **Modified Actuating Rod Release Stab Pin Via Setback Force**
  - ➢ **Stab Pin Has Less Mass**
  - ➢ **Entire Stab Assembly Lubricated**
  - ➢ **Design Proven in Vertical Recovery Tests**



Timer Precision

- **M762**
  - **Settable to 199.9s**
  - **Set Resolution of 0.1 Seconds**
- **MK 432**
  - **Settable to 327.66s**
  - **Set Resolution of 0.01 Seconds**
  - **Greater Precision Needed for SuW Targets**
  - **System Errors Reduce Benefit at Long Range**

Other Changes

- Eliminated Manual Set Capability
- Eliminated Point Detonating Backup Mode
  - MK 432 Will Dud in the Event of a Primary Mode Failure
- New Carbon Filled Ogive
  - Added Protection During Electromagnetic Environmental Effects

Qualification

- 400 Fuzes Completed on 30 March
- First 10 Gun Fired at Yuma on 21 March
  - Only 10 Months from Contract Award
  - 9 Successful Firings, 1 No Test
- 60 Fuzes for EEE Testing
- 102 Fuzes for MIL-STD-331B
- Qualification Completed Summer 2001

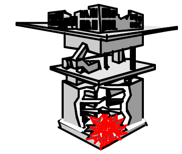
Production

- Scheduled to Begin July 2001
- 14,600 Fuzes Delivery October 2001
- Old Fashion Build to Print Contract
  - No Performance Specification
- On Schedule for a Record Setting Delivery
  - 16 Months from PIP Contract to Completion of Production

Fuzing for Global Interoperability

- **Cockpit Programming to Reduce Logistics**
- **Distributed Arming Systems for Missiles**
- **Tolerant Burst Point Control**

Future Cockpit Programming



Present programming

- Mission planning tools program a PCMCIA card
- PCMCIA card sent to fuze programming site or Mission data sent to fuze programming site and program a PCMCIA card
- Setter unit programs fuze on ground
- Fuze's program checksums hand written on weapon
- Weapon loaded onto specific location of aircraft
- In-flight, fuze mission data can be reprogrammed
- Pilot selects proper weapon from aircraft stores
- Launch weapon

Future programming

- Mission planning develops mission data
- Mission data sent to aircraft
- Aircraft programs fuze, including weapon type
- Launch weapon

Cockpit Programming Improvements

- **Reduce Tactical Response Time by eliminating Ground Programming Processes**
- **Increase Reliability of Launching Proper Weapon from Aircraft. Prevent Launching Weapon with Wrong Mission Data at a Target, when can't Interrogate Weapon on Aircraft**
- **Eliminate Hardware, I.e. Ground Setter Unit**
- **Eliminate Training, I.e. Ground Setter Unit Training**
- **Eliminate Maintenance I.e. Ground Setter Unit Maintenance**
- **Increase Fuze Connector Life and Reliability**
    - **Reduce Number of Connections to Fuze**

Cockpit Programming Plan

- Develop System Safety Approach to program Mission and Weapon Type Parameters
- Obtain Safety Board Approval of Approach
- Implement Approach
- Obtain Safety Board Approval of Design

Distributed Arming Systems

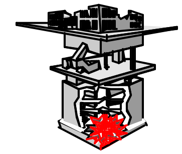
- **Reason for a Distributed Arming System**
  - **Fuze does not have access to Arming Environments, like when Fuze is buried in a Missile**

- **Core Requirements for Distributed Arming System**
  - **MIL-STD-1316 requires Two Independent Arming Environments that Independently Control Arming**
    - **Hardware only (No Software) in at Least One Arming Environment Path**
  - **Unique Code for Arming**

Examples of Distributed Arming Systems

- Free-Flight and Guided Bomb Systems
  - FMU-139 and FZU-48
  - FMU-152 and FZU-55
  - HTSF and FZU-60
- BAT: Umbilical Separation, Air Stream Sensing, and ESAD
- TTPV with a HTSF
- CALCM with a HTSF
- Others

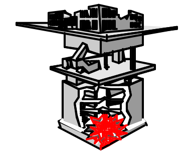
FZU Distributed Arming Systems



- FZU detects Two Independent Arming Environments
  - Lanyard Pull
    - Minimum Lanyard Pull Force
    - FZU Time Windows the Turbine Release Arming Environment
  - FZU Powers Fuze with Post Launch Air Stream
- Unique Power & Turbine Release Signals from FZU-48 & FZU-55
  - Positive for Power
  - Negative for Turbine Release
- FZU-60 Power and Turbine Release Frequencies verified with HTSF & MEHTF

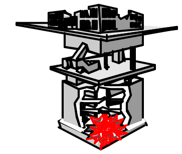
ATK ALLIANT TECHSYSTEMS

Missile Distributed Arming Systems



- Missile programs Fuze
- Missile detects Arming Environments
- Missile builds Unique Arm Code with Arming Environment Data
- Missile provides Arming Power to Fuze
- Missile provides Unique Arm Code to Fuze
- Fuze arms after
    - Timing out Arm Time
    - Detecting Unique Arm Code

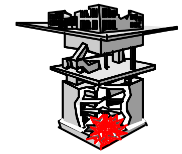
Unique Arm Code



- **Probability of Occurrence << One in a Million to meet MIL-STD-1316's Less than One in a Million arm before launch for System**
- **Ignores Common signals**
  - **Common power: DC, 110Vac. 60hz; 110Vac, 400hz**
  - **Low Frequency Guidance Signals**
- **Provides Immunity to Electromagnetic Environments**

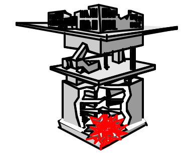
  (HERO, EMV, Other)
- **Built using arming environments like**
  - **Launch**
  - **Deployment of Air Surfaces**
  - **Post Launch Air Stream or Engine Power**
  - **Other**

Tolerant Burst Point Control

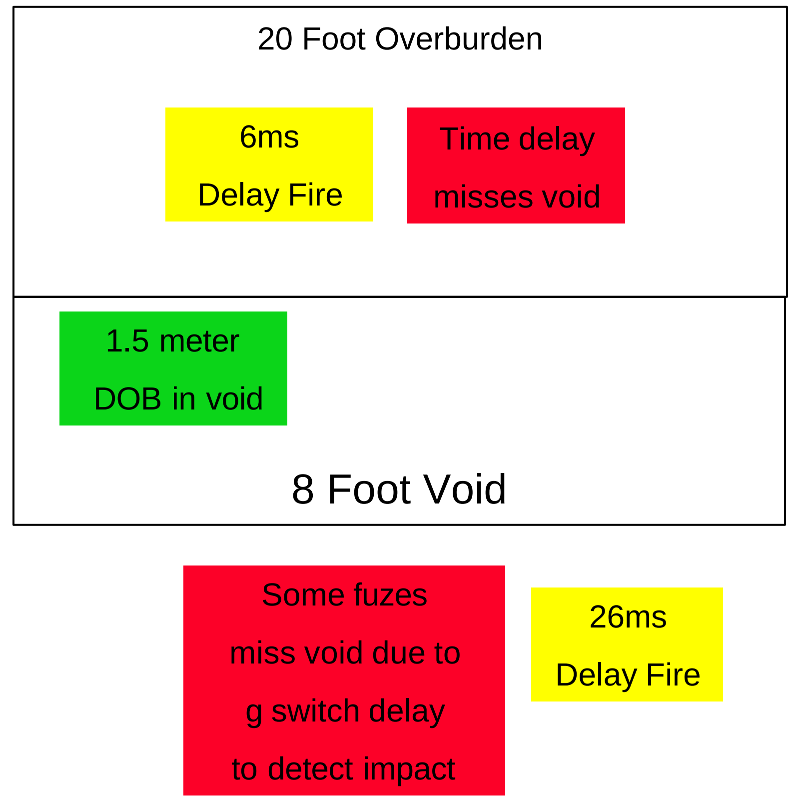


- **Void Detection of HTSF and MEHTF provide Accurate Depth of Burial for**
  - **Varying Overburden**
  - **Multiple Voids**
  - **Unknown Void Lengths**

HTSF & MEHTF Void Burst Point Control



- **Void depth of burial makes target defeat economical with Tolerant burst point control**
- **DOB from void entry fires warhead in void without accurate target intelligence**
  - **Prevents fires before and after voids**
  - **Reduces DOB errors from variations in overburden, impact angles, angle of attack, impact velocity, and warhead turning during penetration**

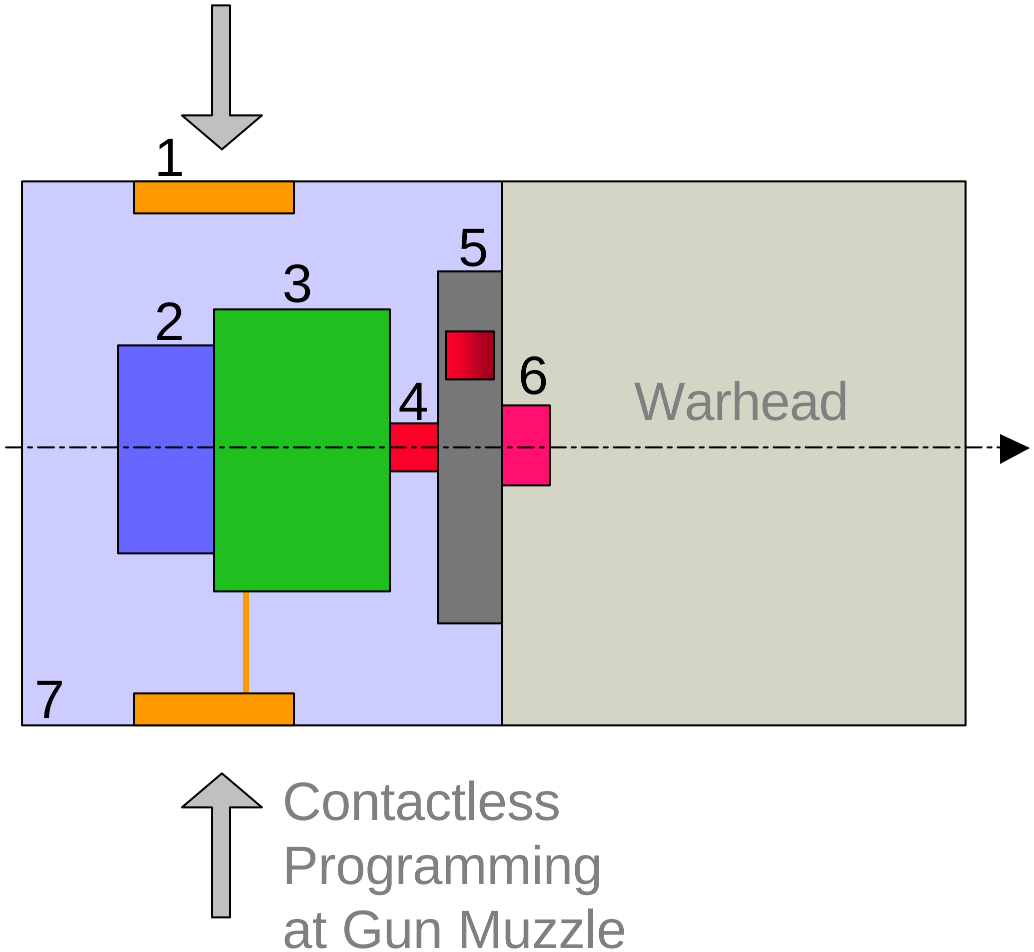


OERLIKON
CONTRAVES

Air Bursting Munition ABM
Medium Calibre Applications

Allan Buckley & Pierre Freymond
Oerlikon Contraves Pyrotec AG
CH-8050 Zurich / Switzerland
ocp-marketing@ocag.ch

ABM Fuze Components



Fuze Components:

1 Receiving Coil

2 Setback Generator

3 Electronic Timer Module

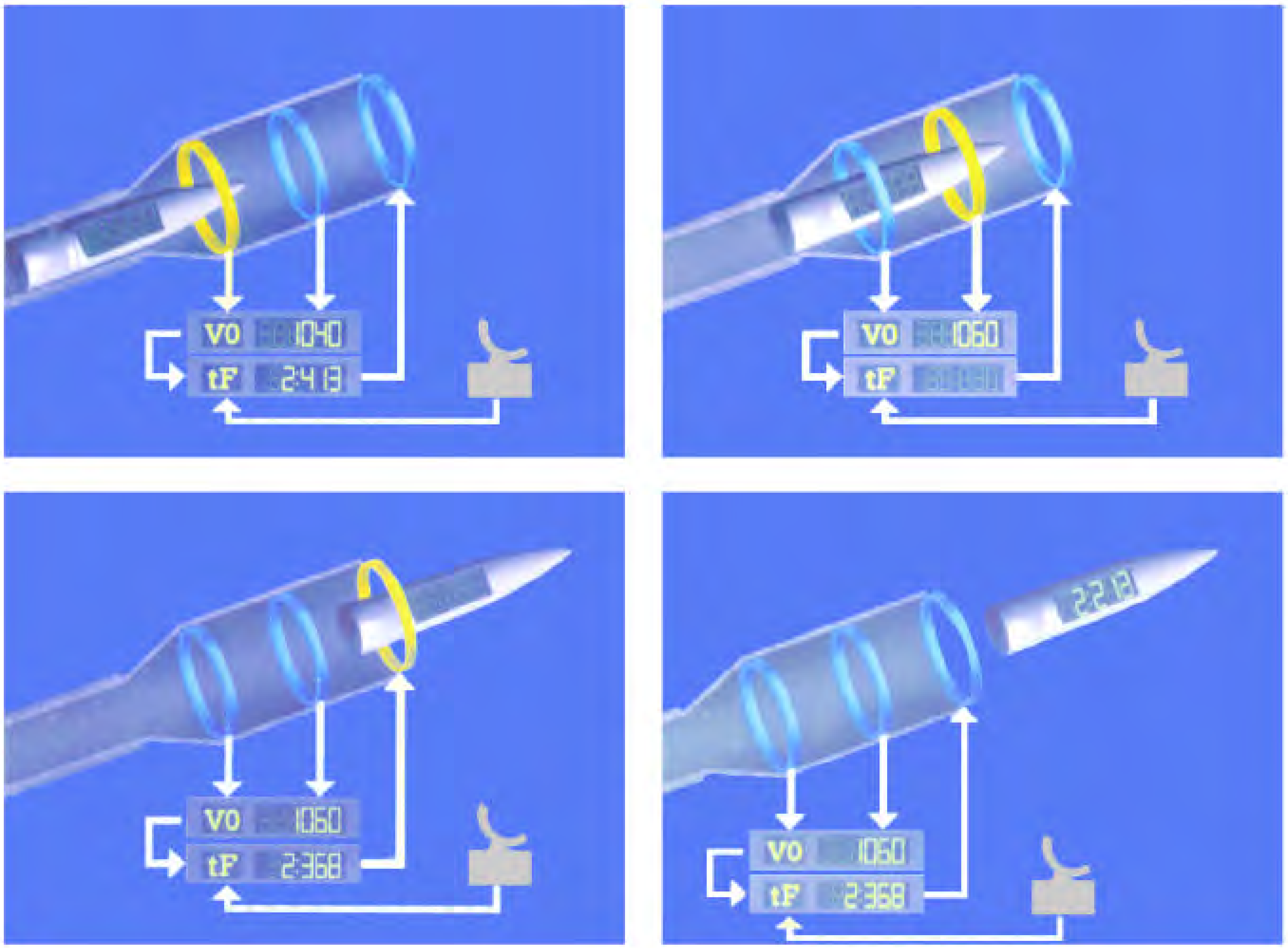
4 Squib

5 Safe & Arm

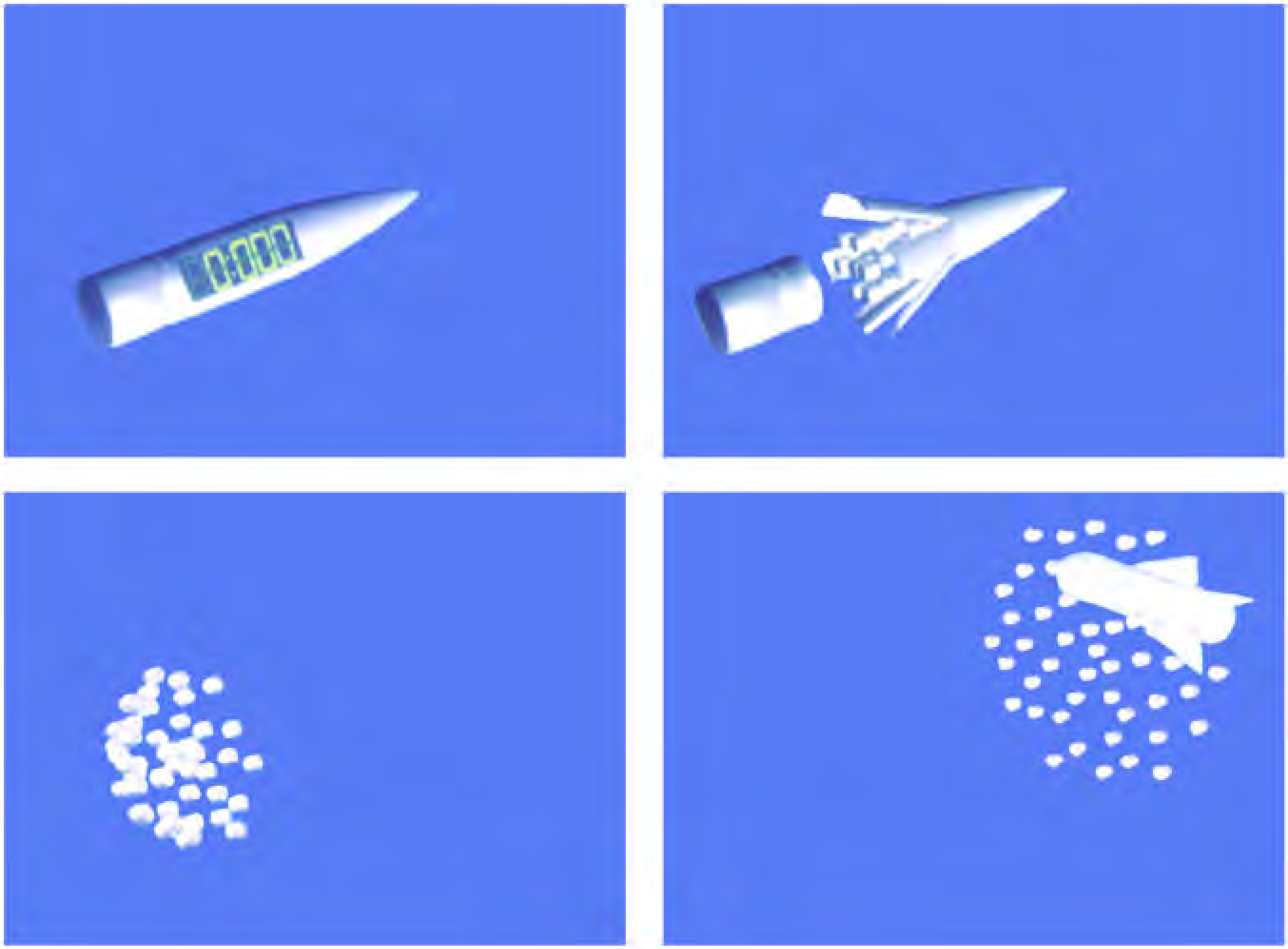
6 Booster, Ejection Charge

7 Base-Fuze Housing

ABM Programming System With On-Line Compensation of MV-Variation



ABM KETF
Subprojectile Payload Delivery



Fuze Challenge!
Programmable Payload Delivery

Precise Time Space Payload Delivery up to 5000 rd/min!

10th Rd:
300 m

1st Rd:
1200 m

„String of Pearls“ at 550 Rd/min of 35mm Ahead-HETF Ammunition

Fuze Programming without & with Compensation of Muzzle Velocity Variation

7 Rd Burst 35mm Ahead-HETF Ammunition at 1600 m Range

ABM Family of Oerlikon Contraves

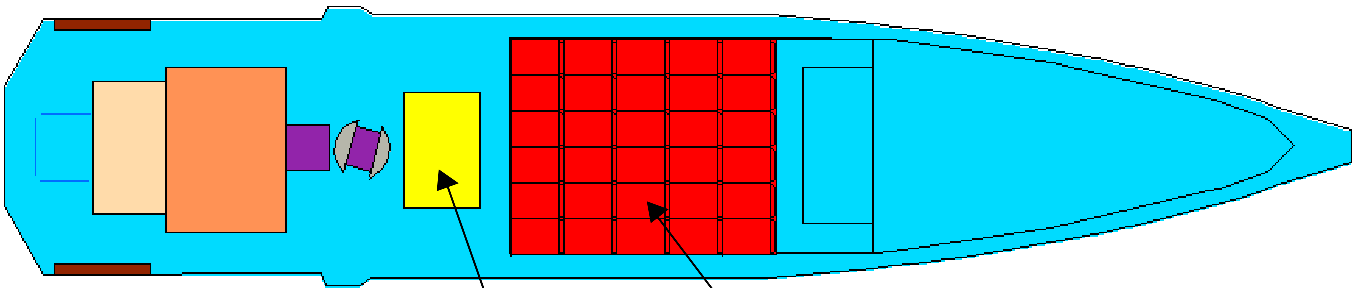
35mm x 228
Ahead
NATO Qual.

30mm x 173
selected for
AAAV - FCT

40mm x 53
selected in
Sweden for
evaluation

Other studies on
following calibers:
25mm x 137
27mm x 145
up to 140 mm

One ABM Fuze System (Ahead) - Two Different Warhead Systems



30mm x 173

(35mm x 228)

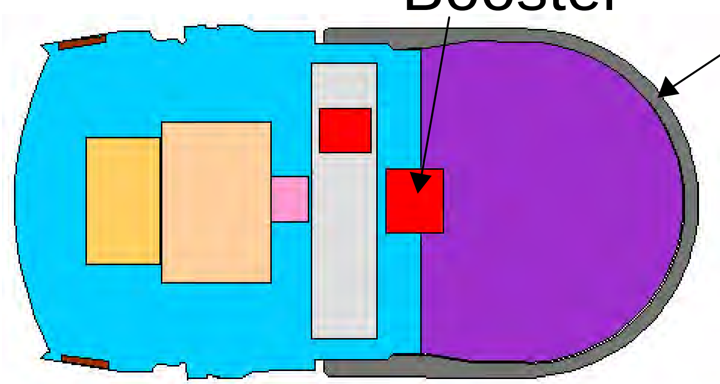
Ejection Charge

Subprojectile Warhead (KETF: Kinetic Energy Time Fuze)

Programmable Base Fuze

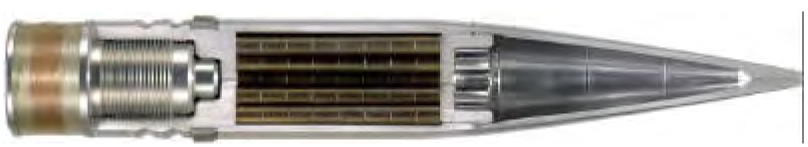
Booster

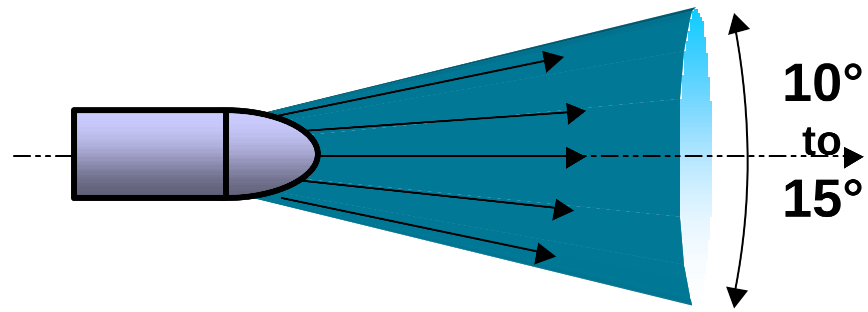
Blast Fragmentation Warhead (HETF: High Explosive Time Fuze)

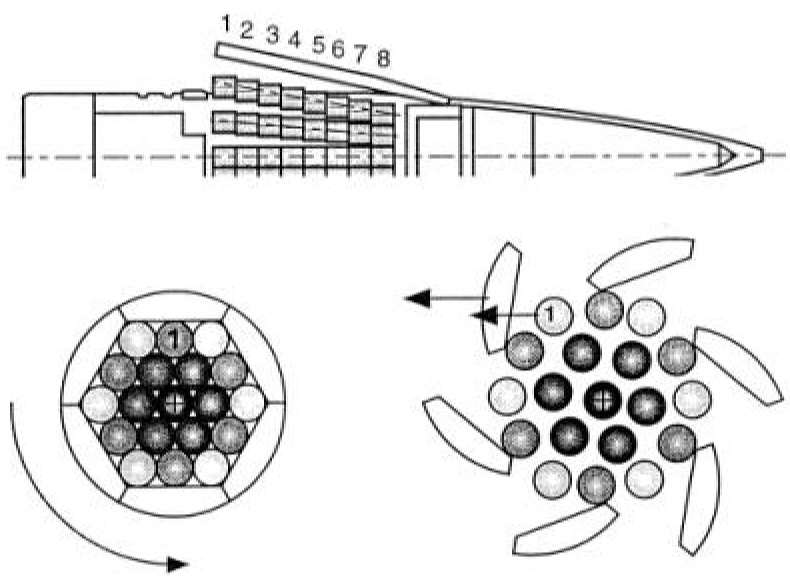


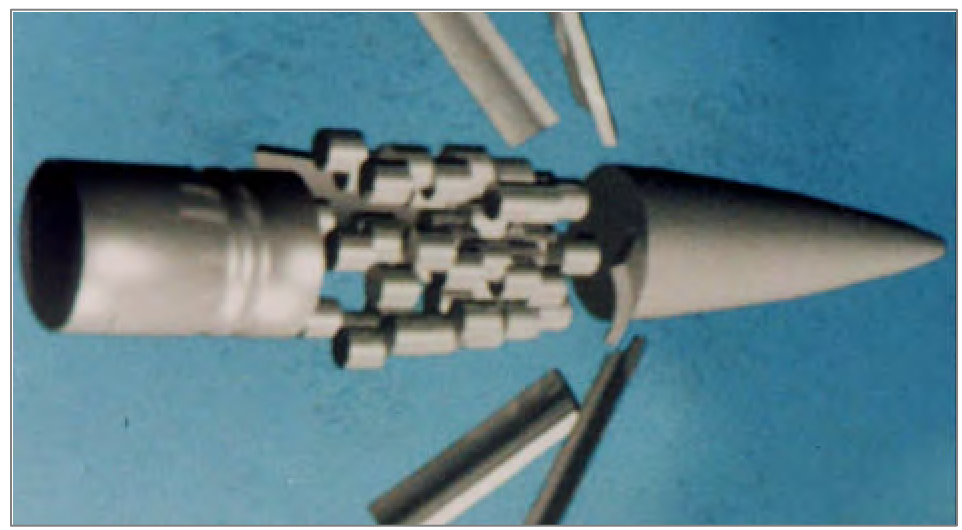
40mm x 53

ABM KETF
Subprojectile Payload Ejection







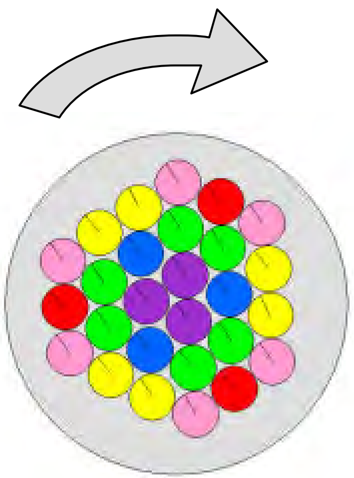


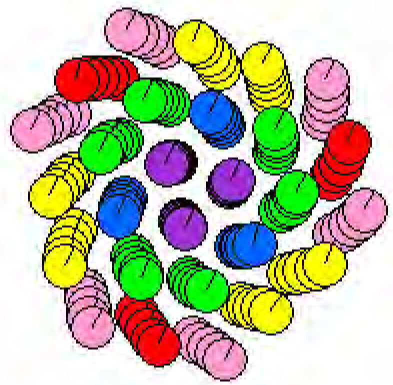
ABM KETF 30mm x 173 Payload Ejection Dynamics

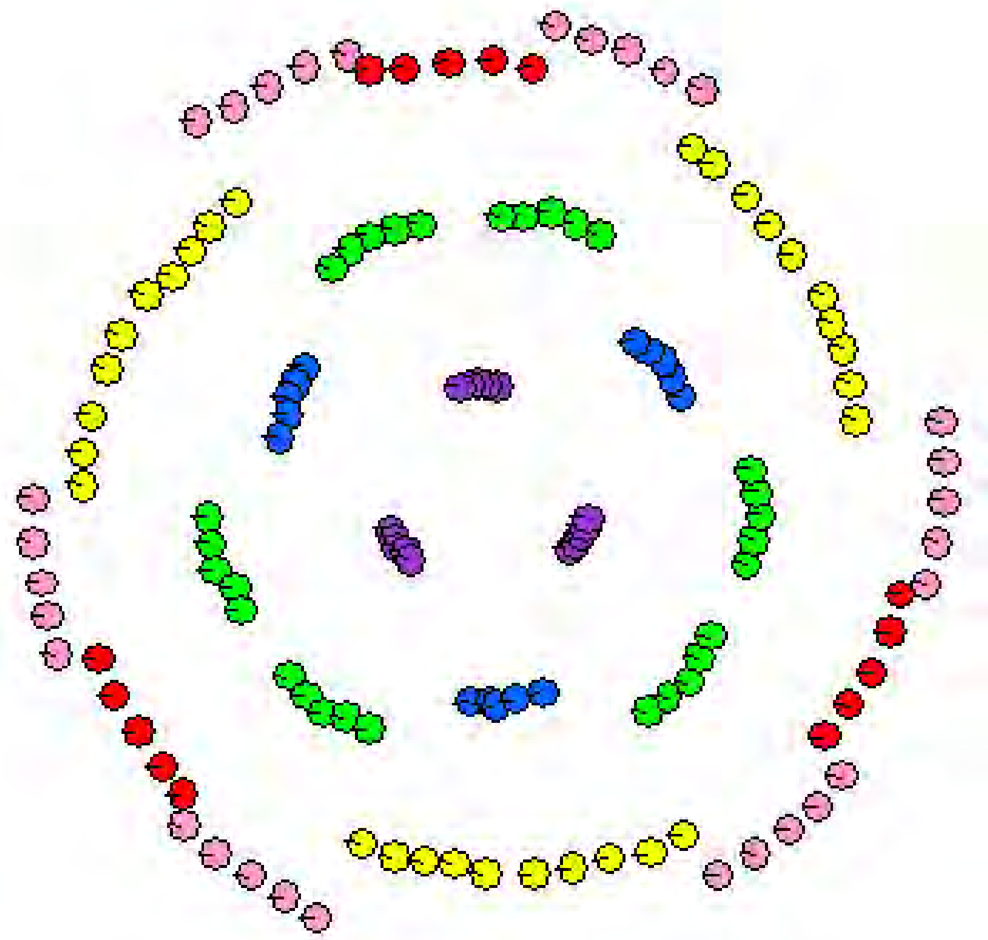
OERLIKON CONTRAVES

135 Subprojectiles at 1.5 g each

5 Layers at 27 Subprojectiles







Time: 0 µs 100 µs 500 µs

ABM KETF 30mm x 173 against ATGW-Bunker at 1 Km Range

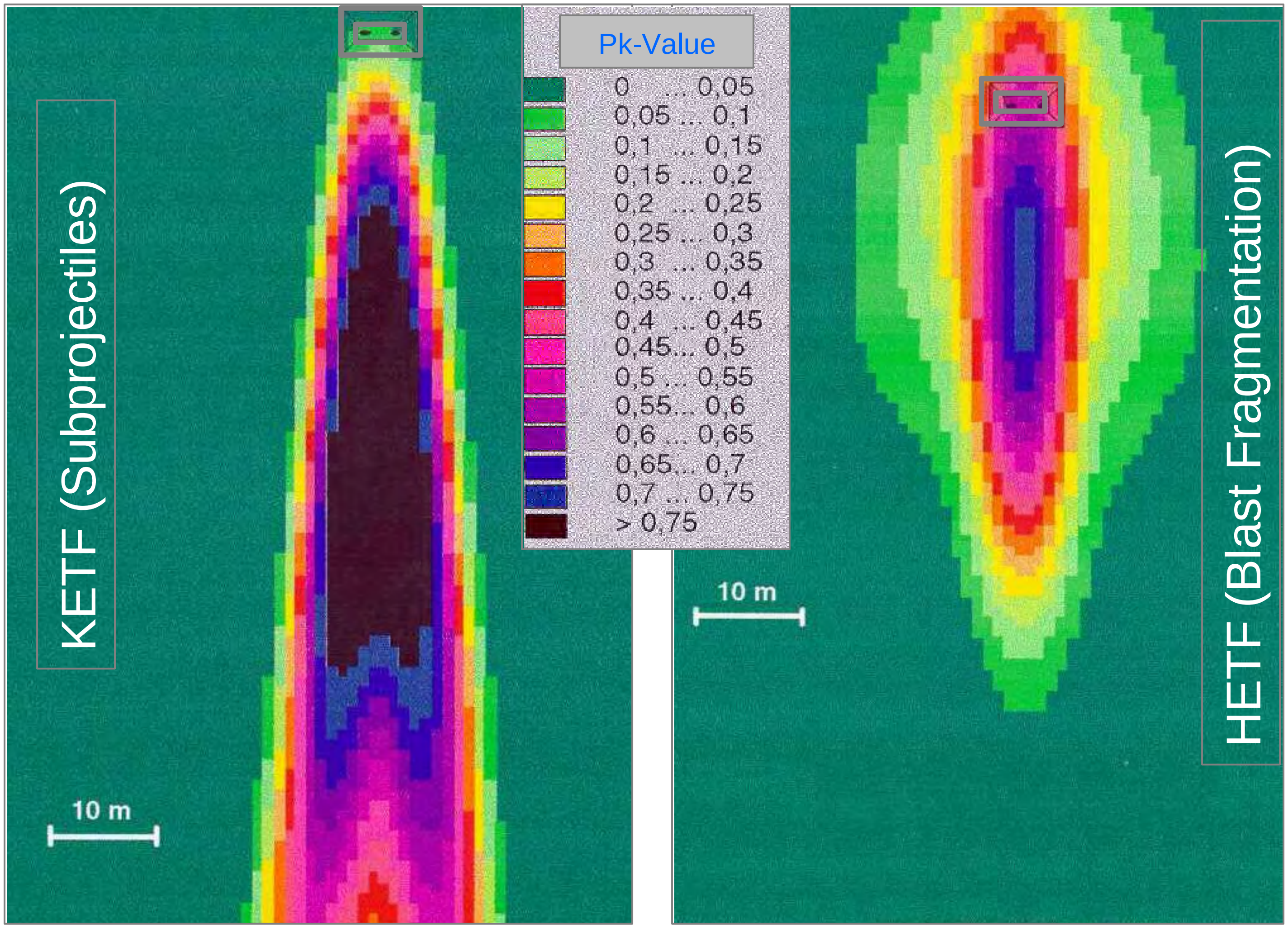
OERLIKON CONTRAVES

Results: Numerous Full Perforations/100% Damage (Demo: Dec.1999)

ABM (KETF & HETF) 35mm x 228 against ATGW-Bunker

Lethality of a

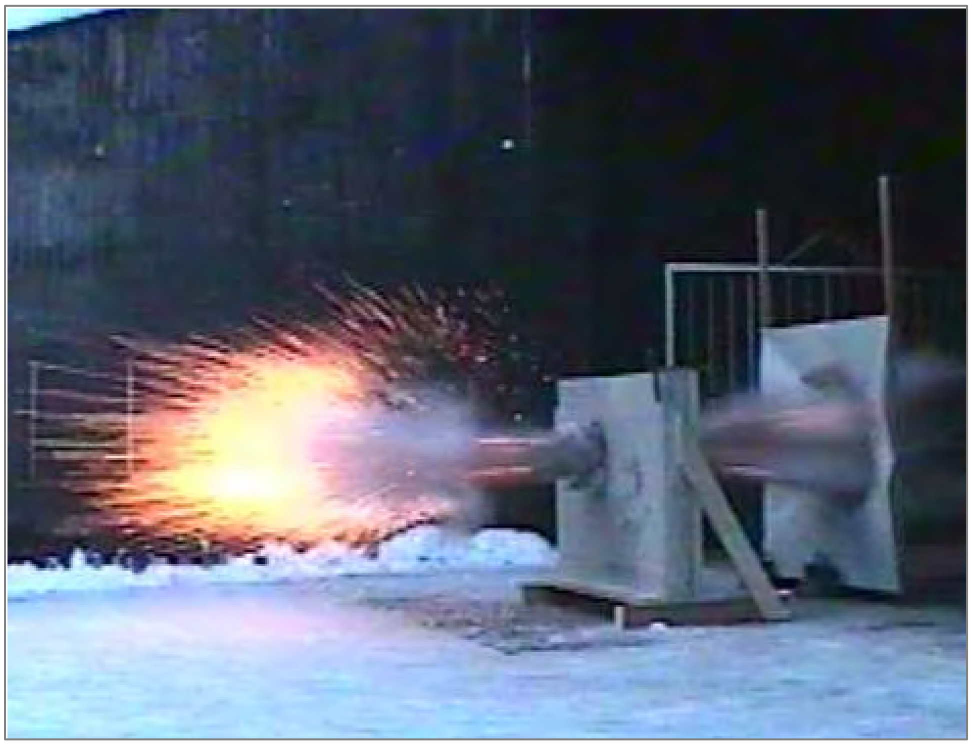
3 Rd Burst against an ATGW Bunker at 1500 m



ABM KETF 30mm x 173 against Urban Target (Unprogrammed Fuze)

OERLIKON CONTRAVES

Target: 20 cm Concrete Wall with double Steel-Structure Reinforced
Results: Target Fully Penetrated

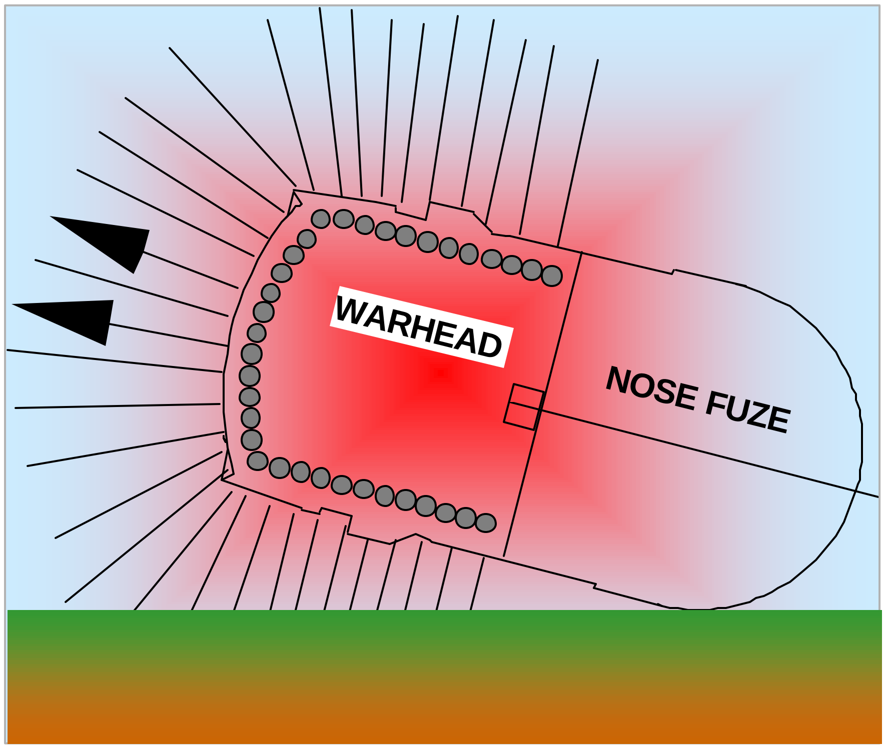


ABM KETF 35mm x 228 Ahead Simulated Lethality > 2 km Range

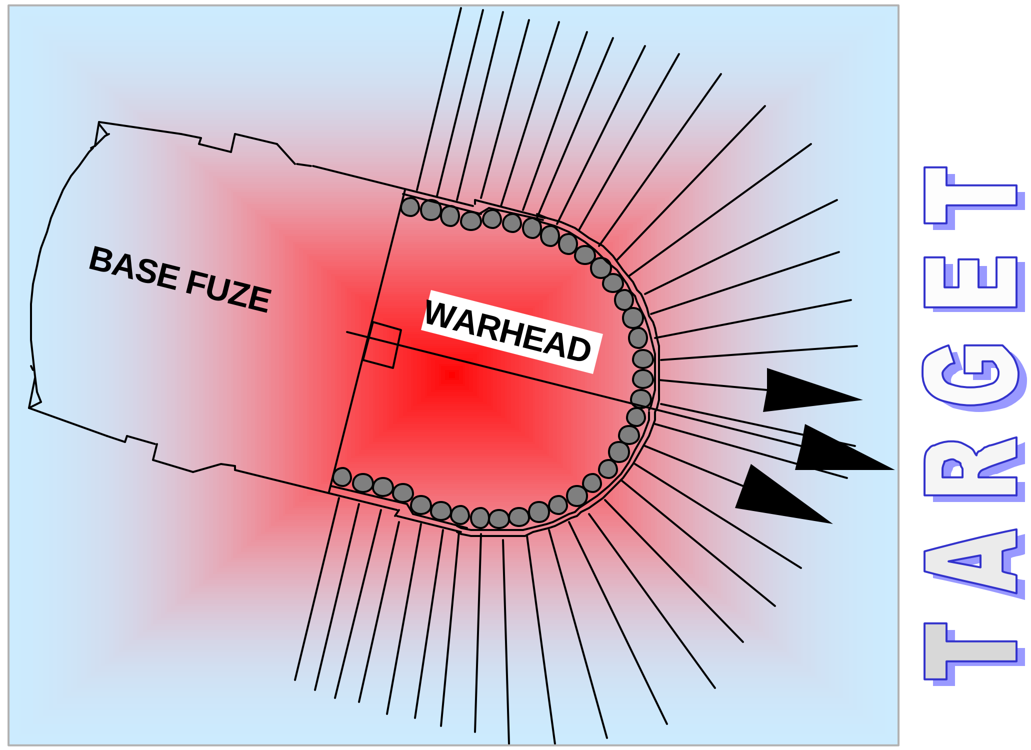
Target: Maverick Missile

Subprojectile Graze Angle Impact < 10°

ABM HETF Basic Concept for 40mm x 53 Automatic Grenade Launcher AGL



Conventional HE Round
(PD-Fuze)

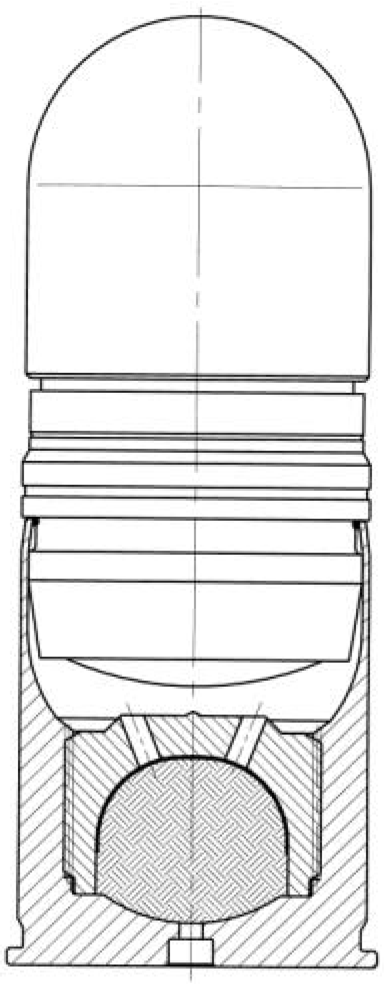


Optimum for
Air Burst Munition

ABM HETF 40mm x 53 for AGL Round Parameters

OERLIKON CONTRAVES

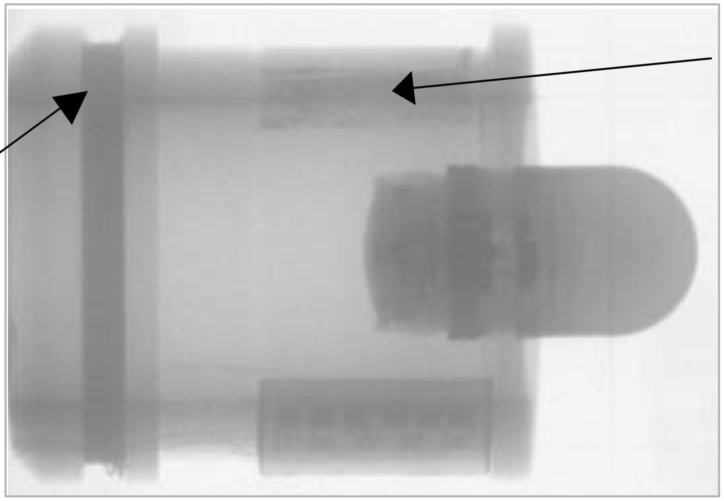
• Round Length	max. 112 mm	
• Round Volume	approx. 130 cm^3	
• Round Mass	350 g	
• Projectile Mass	245 g	
• High Explosive Mass	> 35 g	
• Muzzle Velocity	245 m/s	
• Time of Flight	500 m	2.3 s
	1000 m	5.3 s
	1500 m	9.3 s
	2000 m	15.3 s



ABM HETF 40 mm x 53 Muzzle Programming Device

OERLIKON CONTRAVES

Trigger Coil



Programming Coil

Ammunition Programming Phase in Muzzle Programming Device

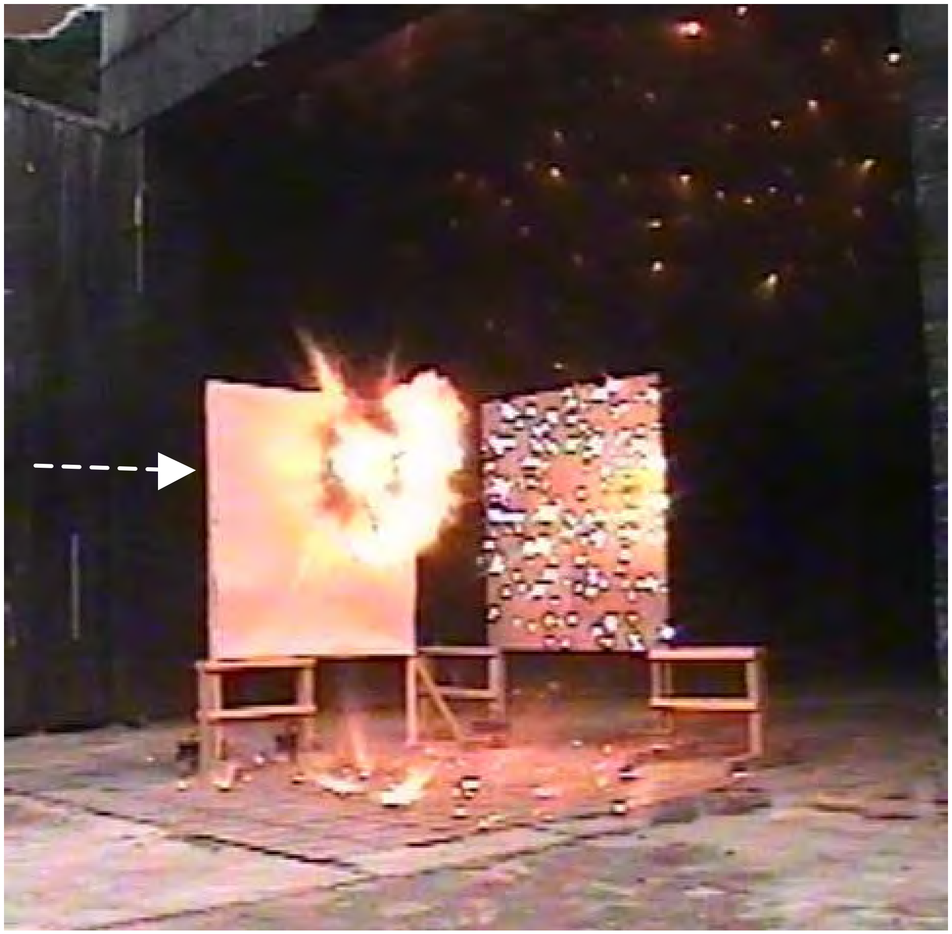
(X-Ray Picture)

Ammunition Programmer & Projectile

Receiving Coil

ABM HETF 40 mm x 53 Firing Trials

OERLIKON CONTRAVES



Range 200 m

Range 1000 m

ABM Fuze (Ahead): Main Features

OERLIKON CONTRAVES

1 Total modularity of components: easy manufacturing, testing & assembly

2 Autonomous power supply (no battery, no storage problems)

3 Allows rapid new fuze developments (recently: 30 mm x 173 & 40 mm x 53)

4 Fuze running time temperature compensated

5 Each bit programmed with double pulse

6 Completeness check on programmed message

7 Reliable component functions at very high g launch (> 100‘000 g)

8 Absolutely ECM safe

9 Applicable to all calibers 25 mm upwards, rifled or smooth bore

10 High calculated system reliability (> 97%) confirmed by years of experience

ABM System (Ahead): Main Advantages

OERLIKON CONTRAVES

1. Smart technology simple and safe in use
2. No rate of fire limitation due to fuze programming
3. Inductive fuze programming at muzzle (not in the gun)
4. On-line compensation for muzzle velocity variation
5. Easy system upgrade: no weapon modification
6. Absolute gun unload safety
7. Insensitive to mud, humidity & other environmental factors
8. Firing through bushes (impact sensor switched off)
9. If no fuze programming required, self-destruct automatically on
10. Lethality level of each round adjustable

TACOM

Lethality, Survivability, Mobility and Sustainment for America's Army

ELECTRONIC DESIGN FOR XM784/XM785 MORTAR TIME FUZE

PRESENTED TO THE NDIA FUZE SYMPOSIUM

APRIL 18, 2001

TOM WALKER
ANDY LESHCHYSHYN

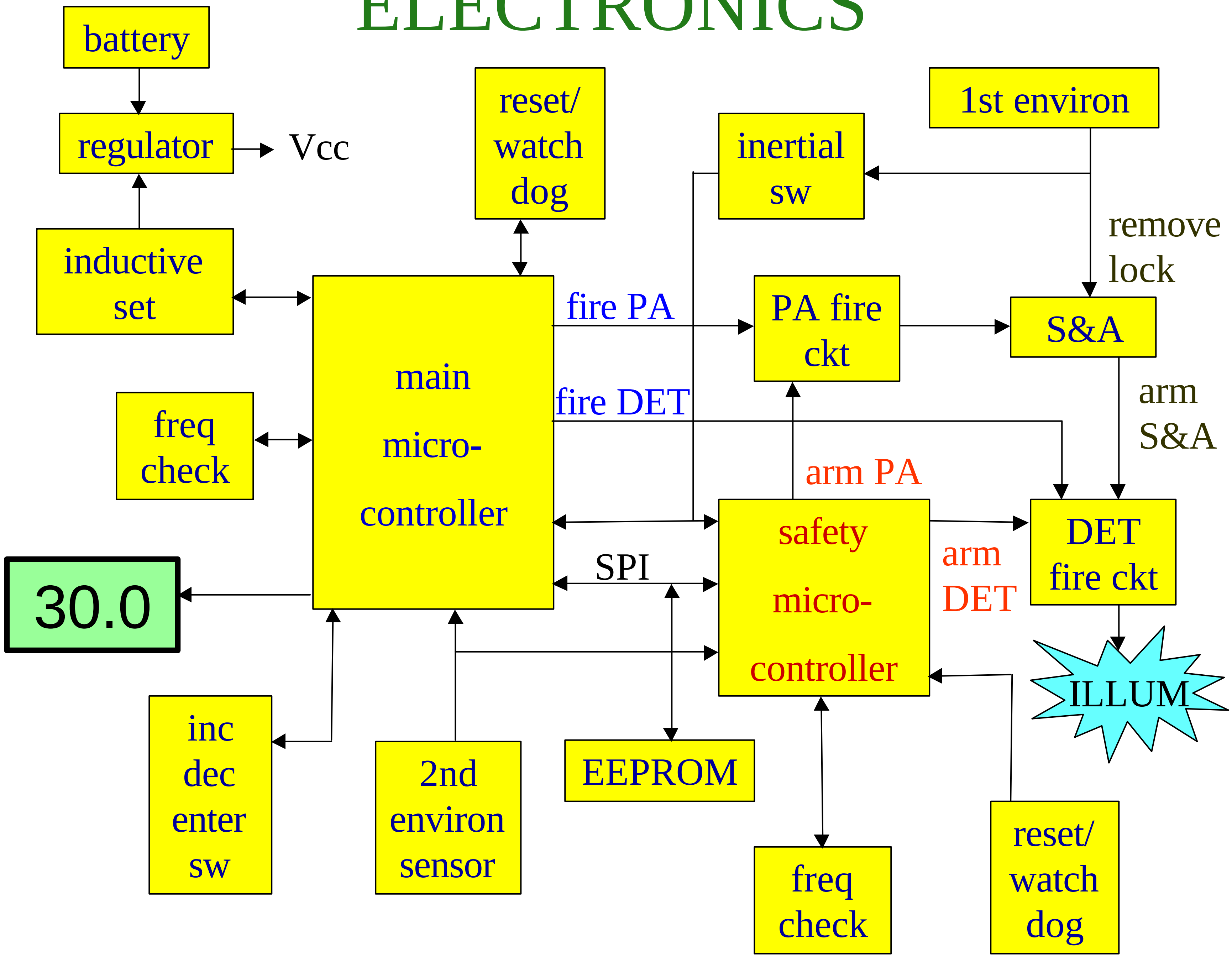
INTRODUCTION TO IN-HOUSE EFFORT

- Electronic design
- Schematic
- Breadboard
- PWB
- Software
- Battery
- LCD
- 2nd environment

MORTAR TIME FUZE

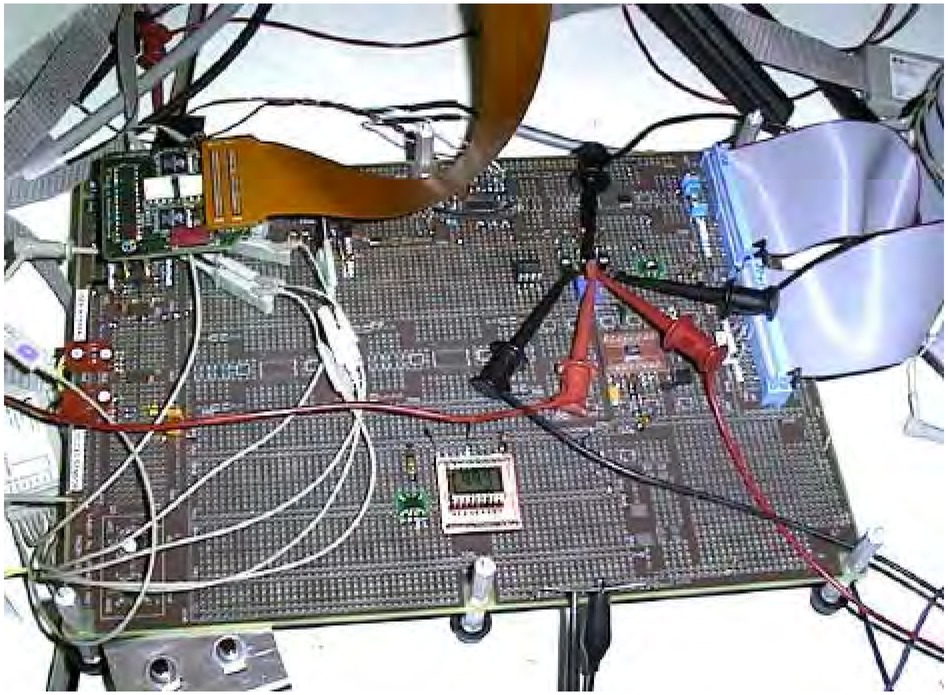
- Hand-settable
  - ogive inc/dec switch
  - enter switch
  - backlight LCD
- 5 - 99.9 $\pm$ 0.1 sec
- Dual micros
- Dual XTAL timebases
- EEPROM data recorder
- Built in test (BIT)
- Dual watchdog timers
- 30 day battery life
- Sleep mode
- Inductive set
- EOD batt discharge
- PD backup

ELECTRONICS



CUSTOM BREADBOARD

- PWR & GND plane
- Surface mount IC footprints
- Two PIC emulators



PROTOTYPE PWB

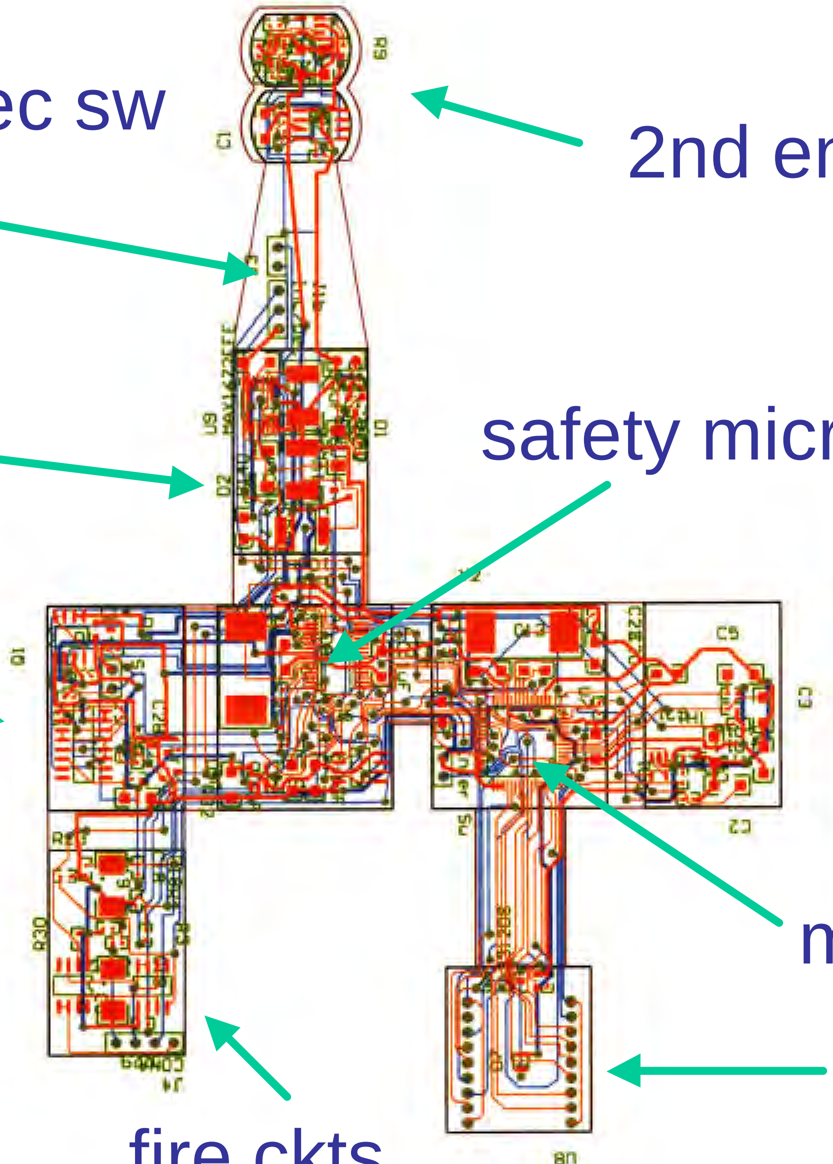
battery, inc/dec sw interface

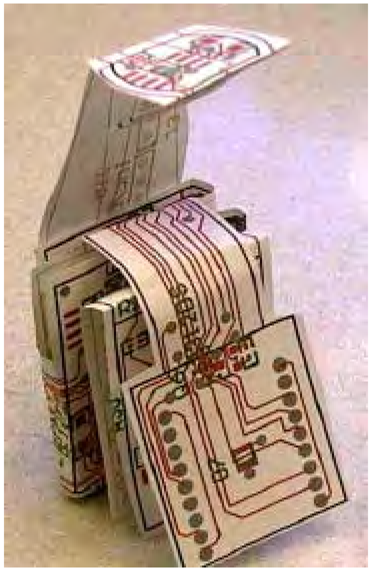
2nd environ.

regulator

safety micro

inductive



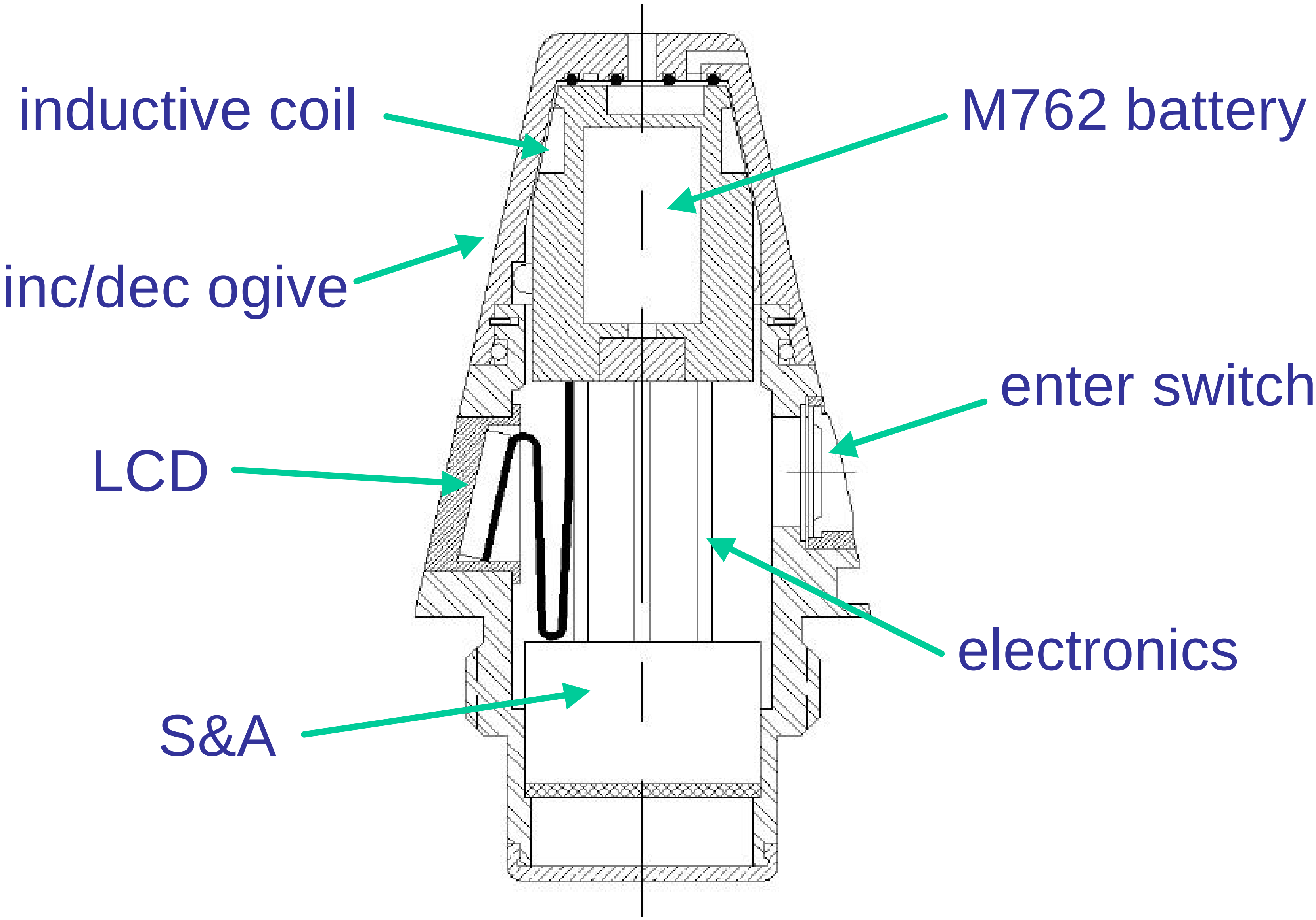


main micro

LCD

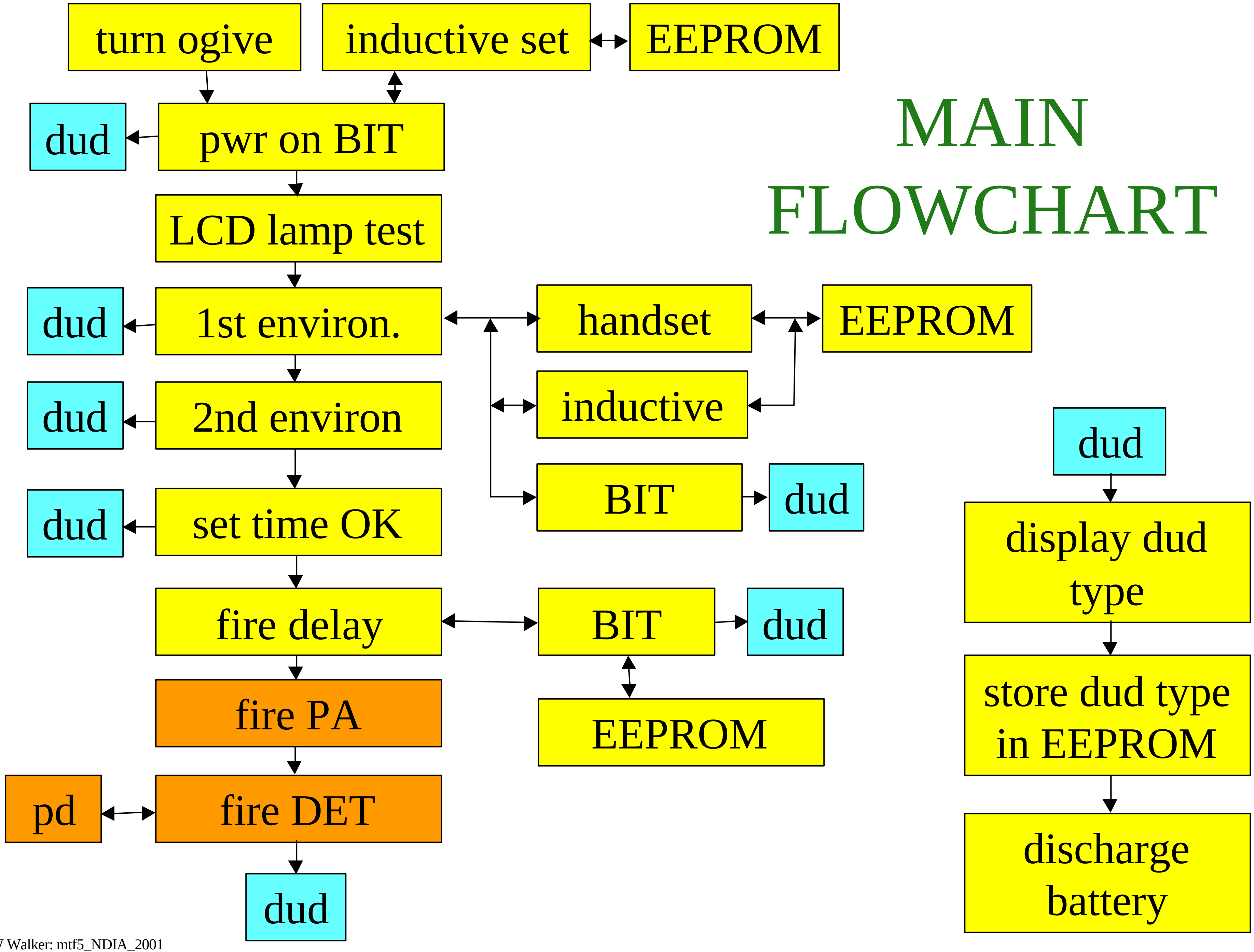
fire ckts

CROSS-SECTION VIEW

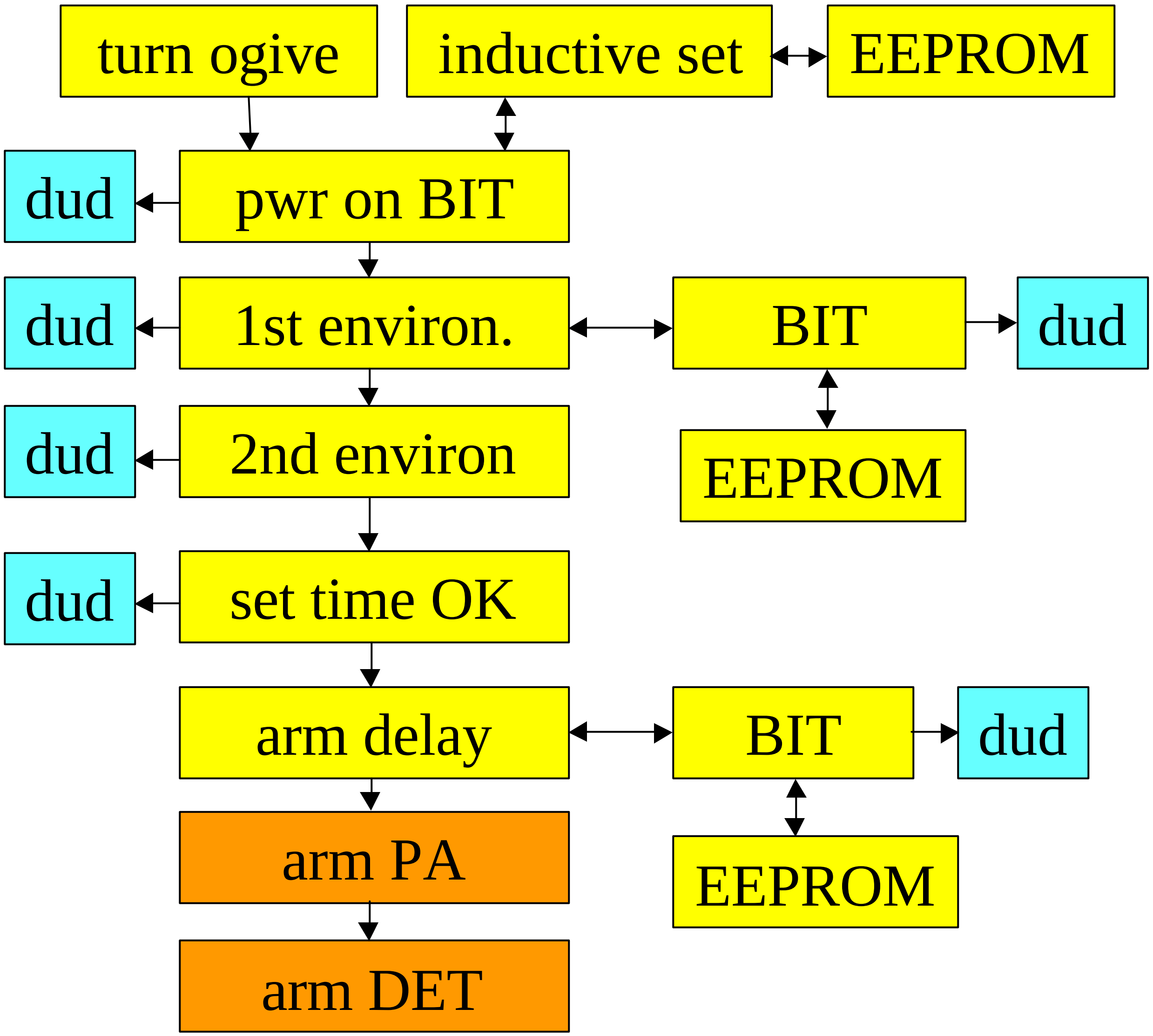


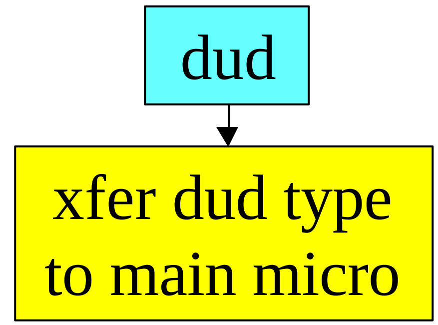
SOFTWARE DEVELOPMENT

MAIN FLOWCHART



SAFETY FLOWCHART



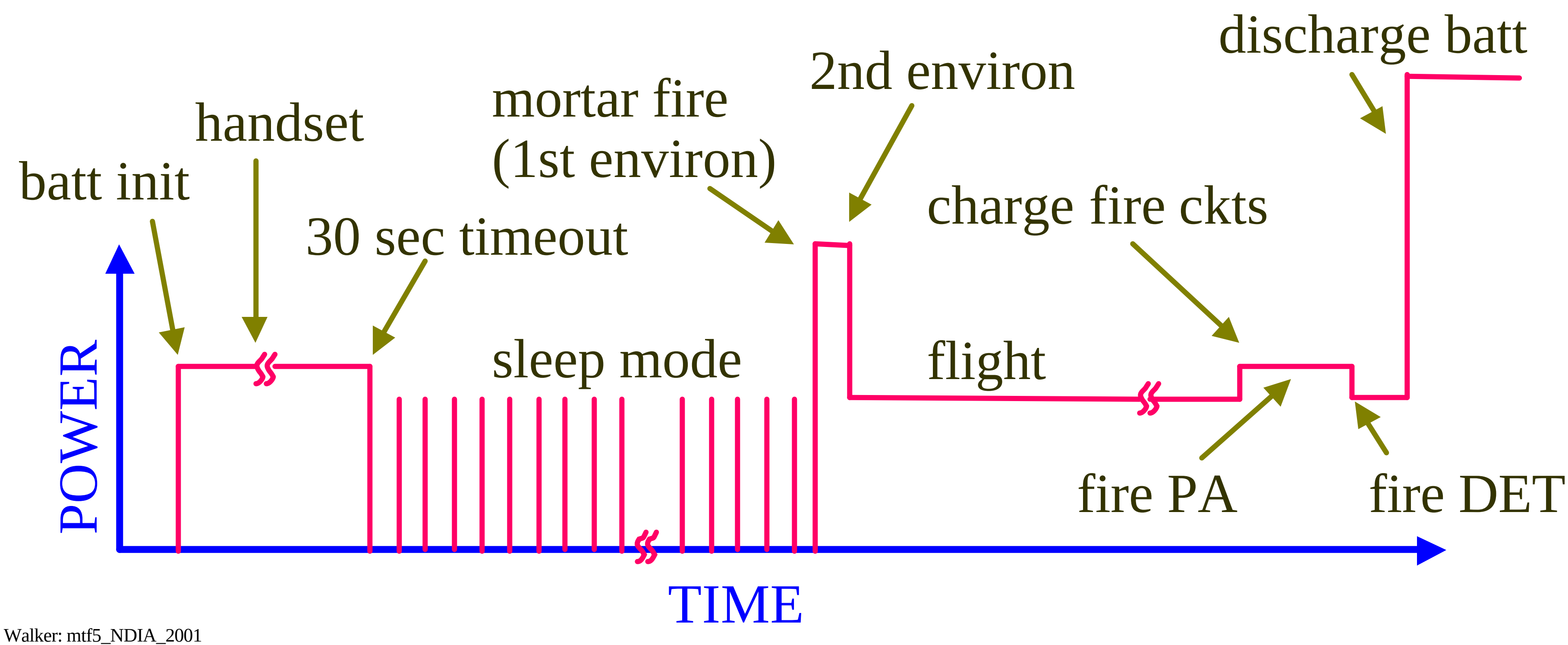


- BIT
  - RAM
  - I/O
  - clock freq
  - battery voltage
  - safety micro

POWER CONSUMPTION

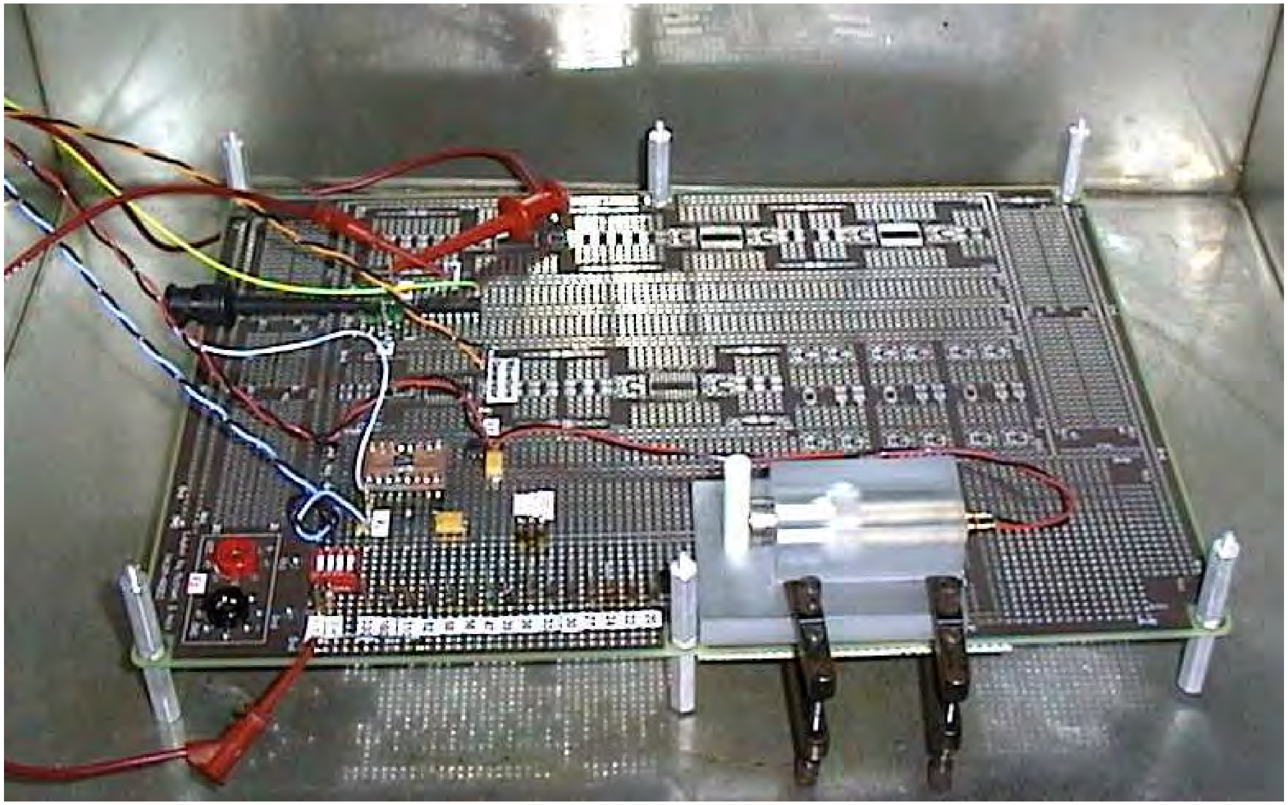
- Electronics
  - 33 mW active
  - 0.5 mW sleep
- Backlight = 7 mW

- 2nd environment
  - 45 mW gun muzzle
  - 5 mW pressure
- Fire ckts = 1 mW



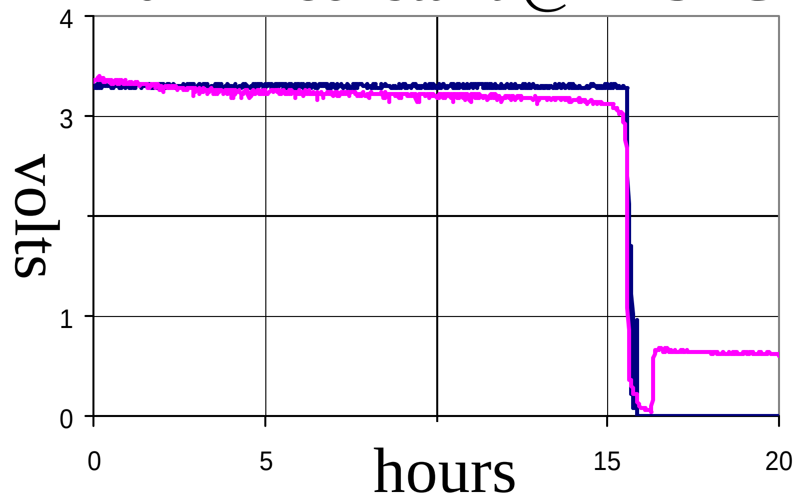
BATTERY

- 3 day requirement
- M762 battery
- 3.6 volt lithium thionyl chloride

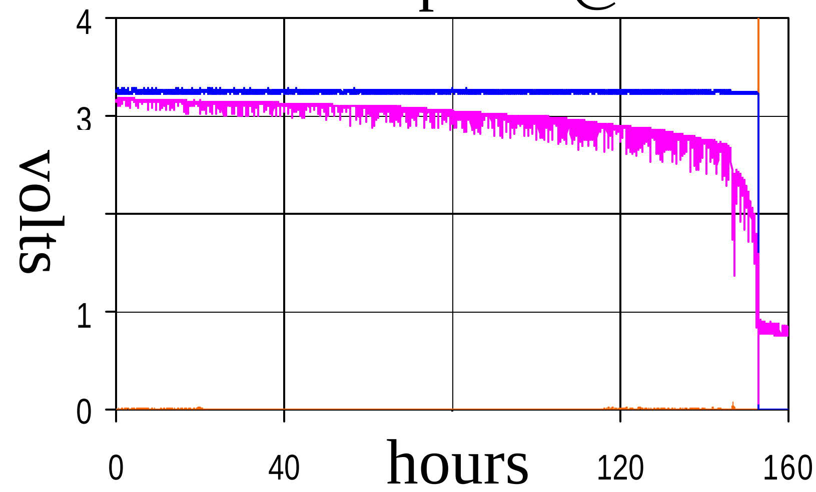


BATTERY TESTS

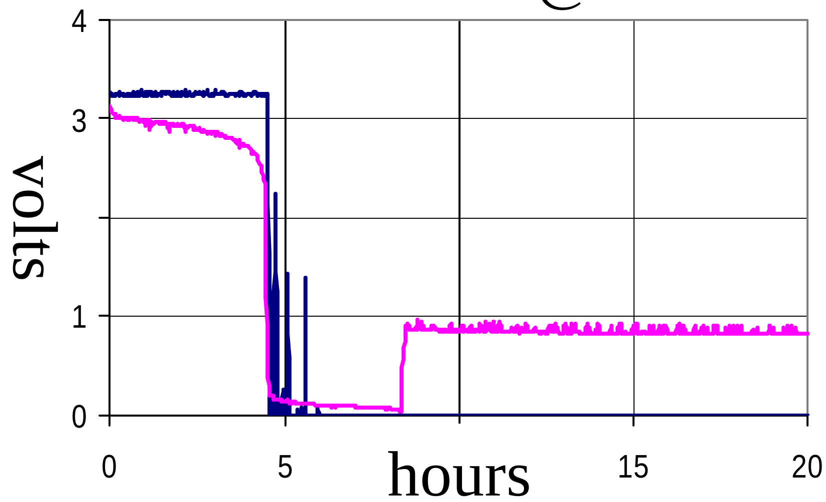
10 mA constant @ +23 ^oC



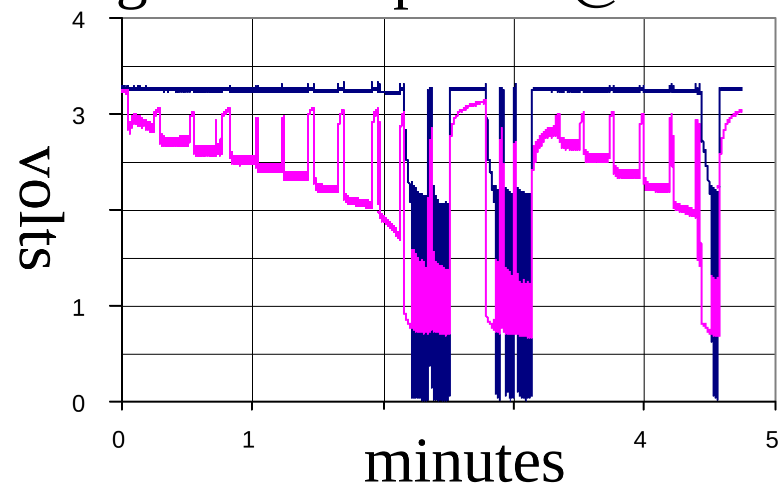
10 mA 1/20 pulse @ -43 ^oC



10 mA constant @ -43 ^oC



high current pulses @ -43 ^oC

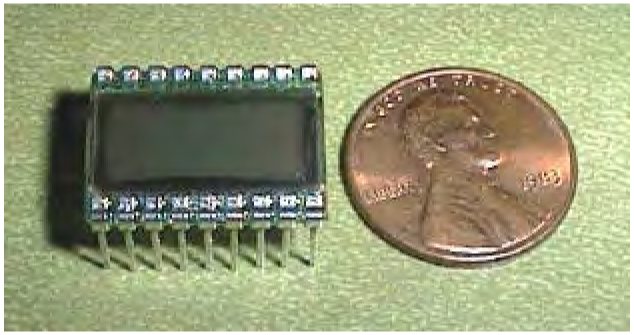


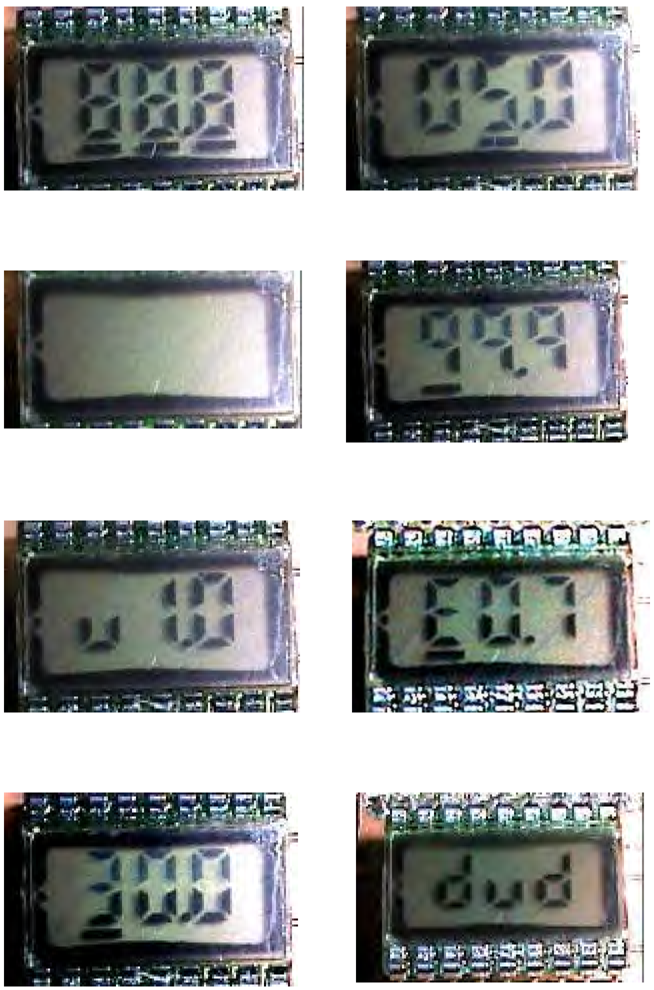
BATTERY TEST RESULTS

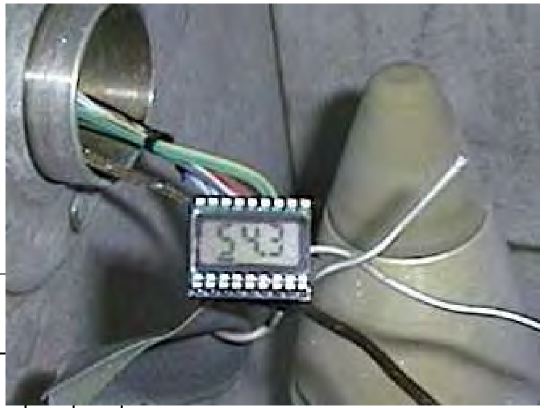
actual			
TEST	**TEMP (^oC)**	**TIME (hrs)**	**CAPACITY (mA hrs)**
10 mA constant	+63	17	170
10 mA constant	+23	15	150
10 mA constant	-43	5	50
10 mA @ 1/20 duty cycle	-43	150	75
10 mA @ 1/10,000 duty cycle	-43	3,125 days	75
extrapolated			

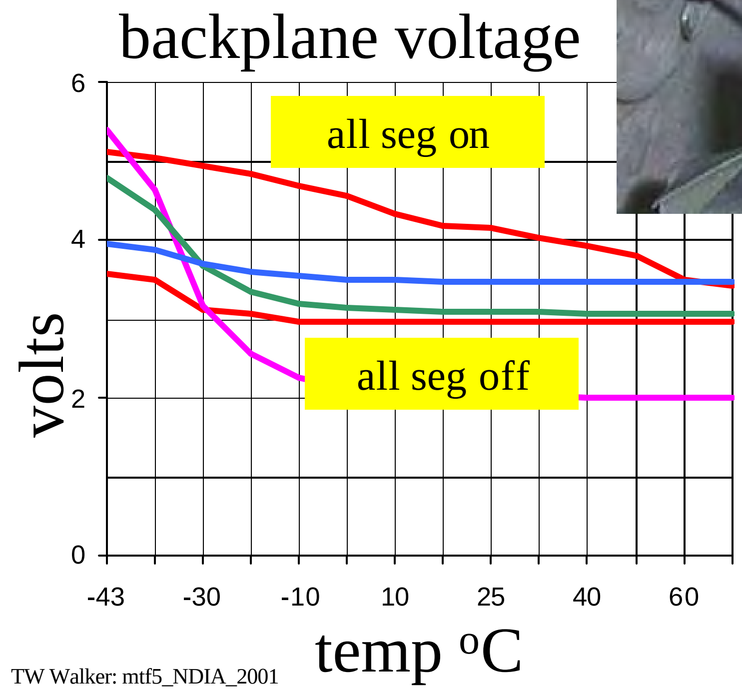
LCD

- 2:1 multiplex
- Adj backplane voltage over temp
- PWM backlight: 30 sec turnoff
- M762 derivative



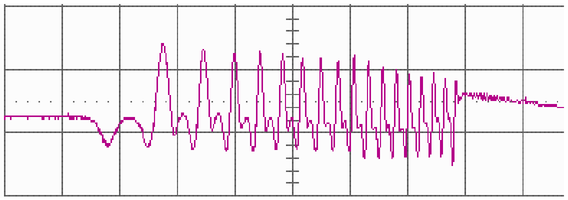




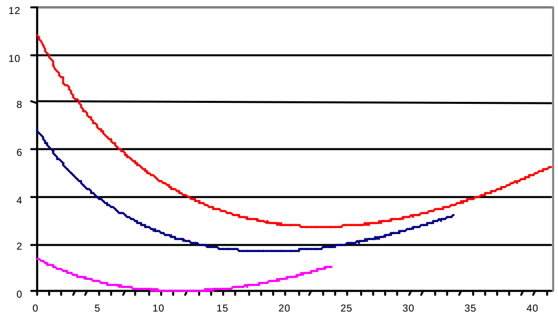


2nd ENVIRONMENT

- Gun muzzle exit sensor
  - 3 gun tubes

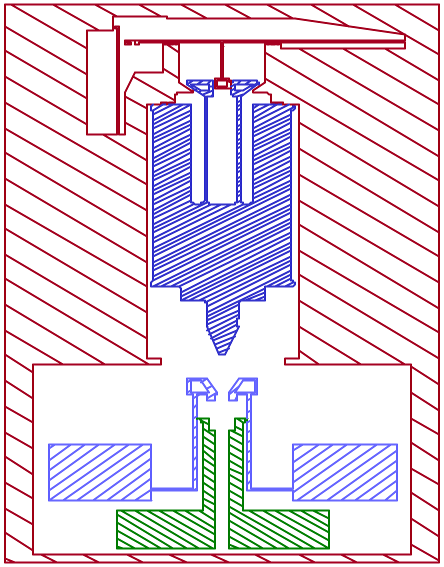


- Flight pressure sensor
  - low charge

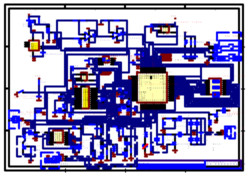
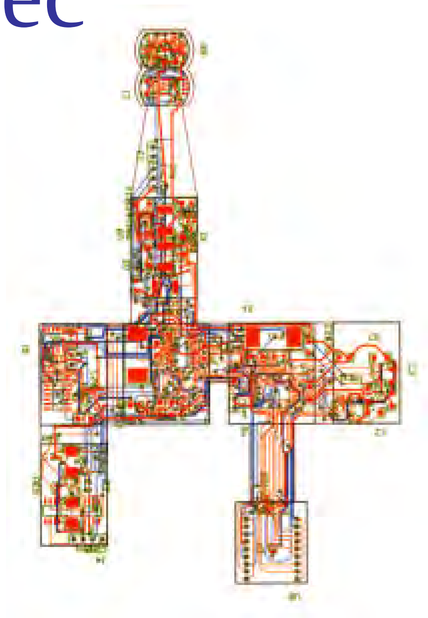
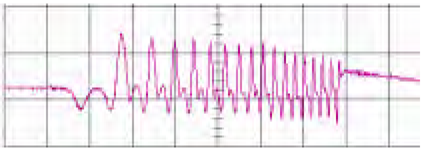


FUTURE WORK

- Conduct safety review of system electronics
- Continue evaluation of 2nd environ sensors
- Design MEMS inertial switch
- Fabricate handset models
- Obtain user feedback
- Award EMD contract



CONCLUSION

- In-house electrical design meets spec
- Fully functional breadboard
- Schematic 
- Prototype flex-circuit PWB 
- Software program for both micros
- M762 battery 
- LCD 
- 2nd environment prototypes 

JAMI
Flight Termination System
A Cooperative Development
Between
NAWC/CL and KAMAN

Dale Spencer, Presenter
Andy Yuenger, Co-Author

45th Annual Fuze Conference

Long Beach, California

April 18th , 2001

Overview

- **Joint Advanced Missile Instrumentation**
  - **Roles**
  - **System**
- **FTSA**
  - **Requirements**
  - **Features**
  - **Block Diagram**
  - **Design/ Implementation**
  - **Test Results**
  - **Status**
  - **Plans**

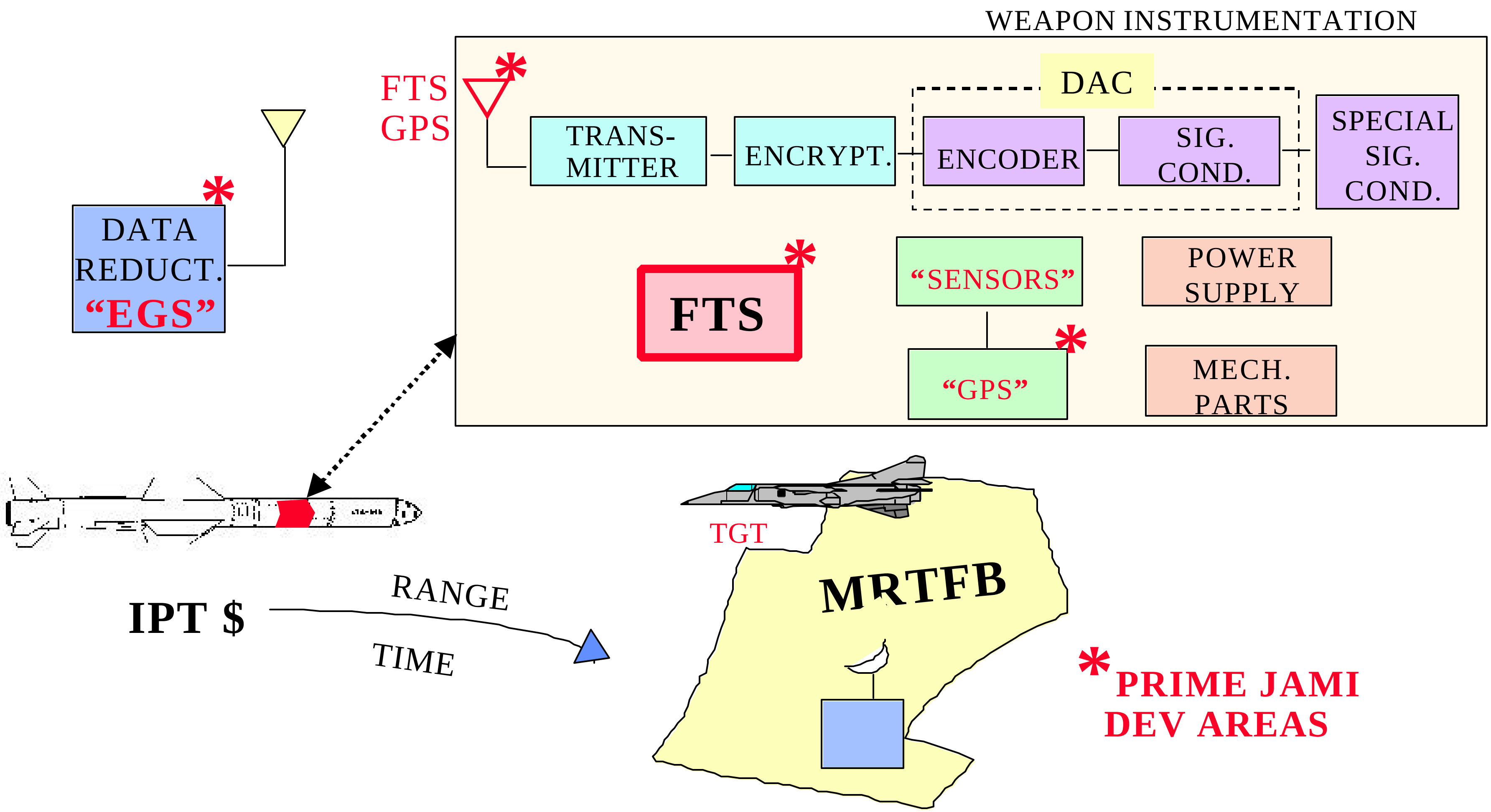
DEVELOPMENT UNDER CRADA

- Cooperative Research and Development Agreement
  - Raymond Engineering Operations (REO)
  - Signed 12 April 1999
  - Division of Responsibilities
    - **China Lake**
      - **Electrical/Explosive Design and Development**
      - **Environmental Testing**
    - **REO**
      - **Packaging**
      - **Hardware Manufacturing**

JAMI FTS TEAM

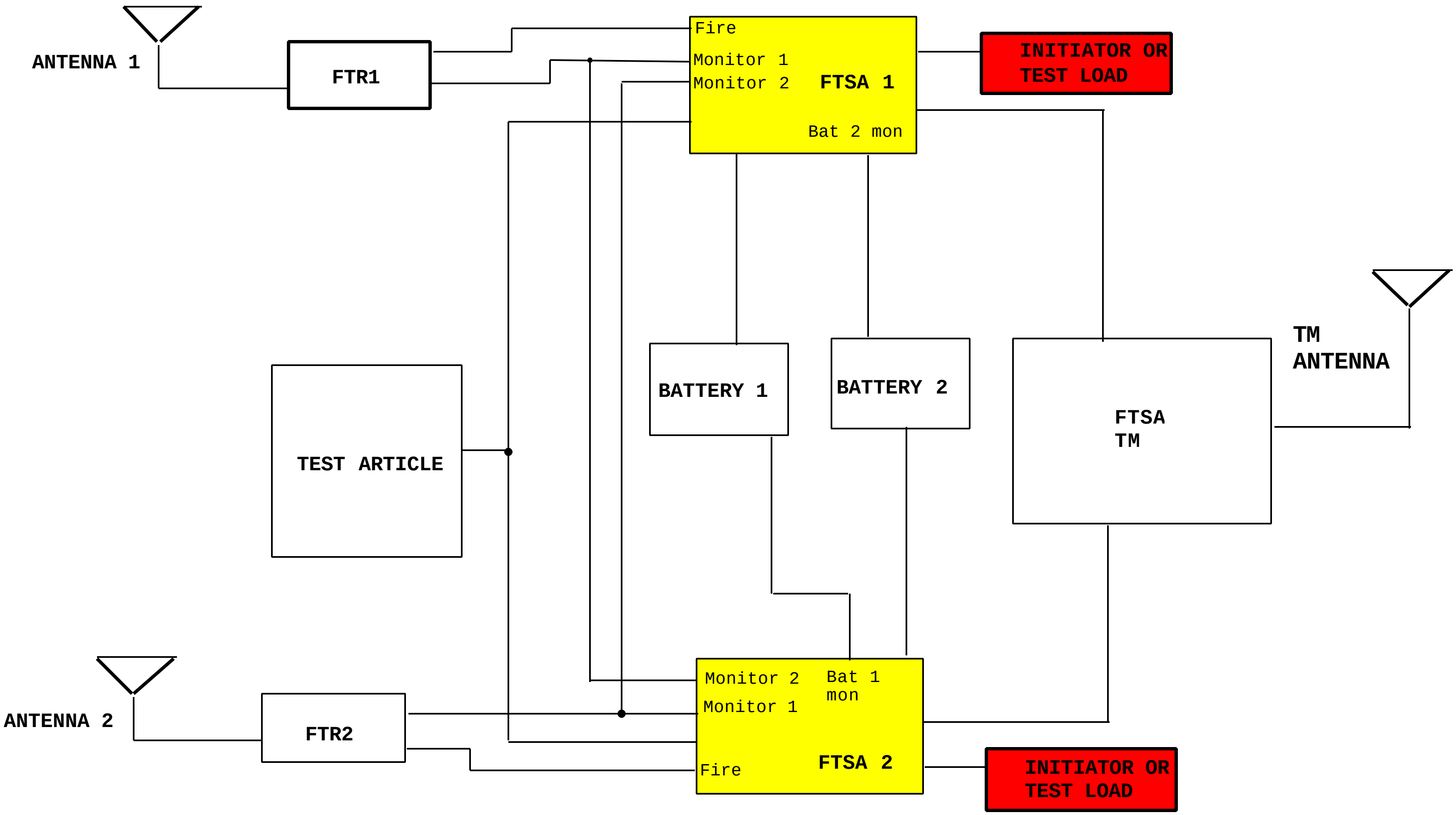
- **Program Dir :** **Mr. Don Scofield, NAWCWD, China Lake**
- **Navy Deputy:** **Mr. Dave Powell, NAWCWD, Pt Mugu**
- **Project Engr:** **Mr. Andy Yuenger, NAWCWD, China Lake**
- **EE Design (Past):** **Mr. Mike Haddon, NAWCWD, China Lake**
- **EE Design (Present):** **Mr. Gabe Soto, NAWCWD, China Lake**
- **Analyst:** **Mr. Jim McVay, NAWCWD, China Lake**
- **Industry Partner: Kaman Aerospace Corporation/ Raymond Engineering**
  - **ME Design:** **Mr. Robert Spooner**
  - **FCDC Interface:** **Mr. Ted Horbacewicz**
  - **Test Engineer:** **Mr. Mario Fasulo**
  - **Reliability & Safety:** **Mr. Pete Rohner**
  - **Firmware:** **Mr. Pete Solari**
  - **Project Engineer:** **Mr. Dale Spencer**

JAMI System



WEAPON INSTRUMENTATION
FTS
GPS
*
TRANS-
MITTER
ENCRYPT.
DAC
ENCODER
SIG.
COND.
SPECIAL
SIG.
COND.
*
DATA
REDUCT.
"EGS"
*
FTS
"SENSORS"
POWER
SUPPLY
*
"GPS"
MECH.
PARTS
TGT
MRTFB
IPT $
RANGE
TIME
*
PRIME JAMI
DEV AREAS

FTSA in JAMI System



FTSA VS S&A

- FTSA
  - Overriding Concern is to Not Allow the Weapon to Go Outside the Range Footprint
  - Defining Specification is RCC 319-99
- S&A
  - Overriding Concern is to Not Allow Unintended Initiations
  - Defining Specification is Mil-Std-1316

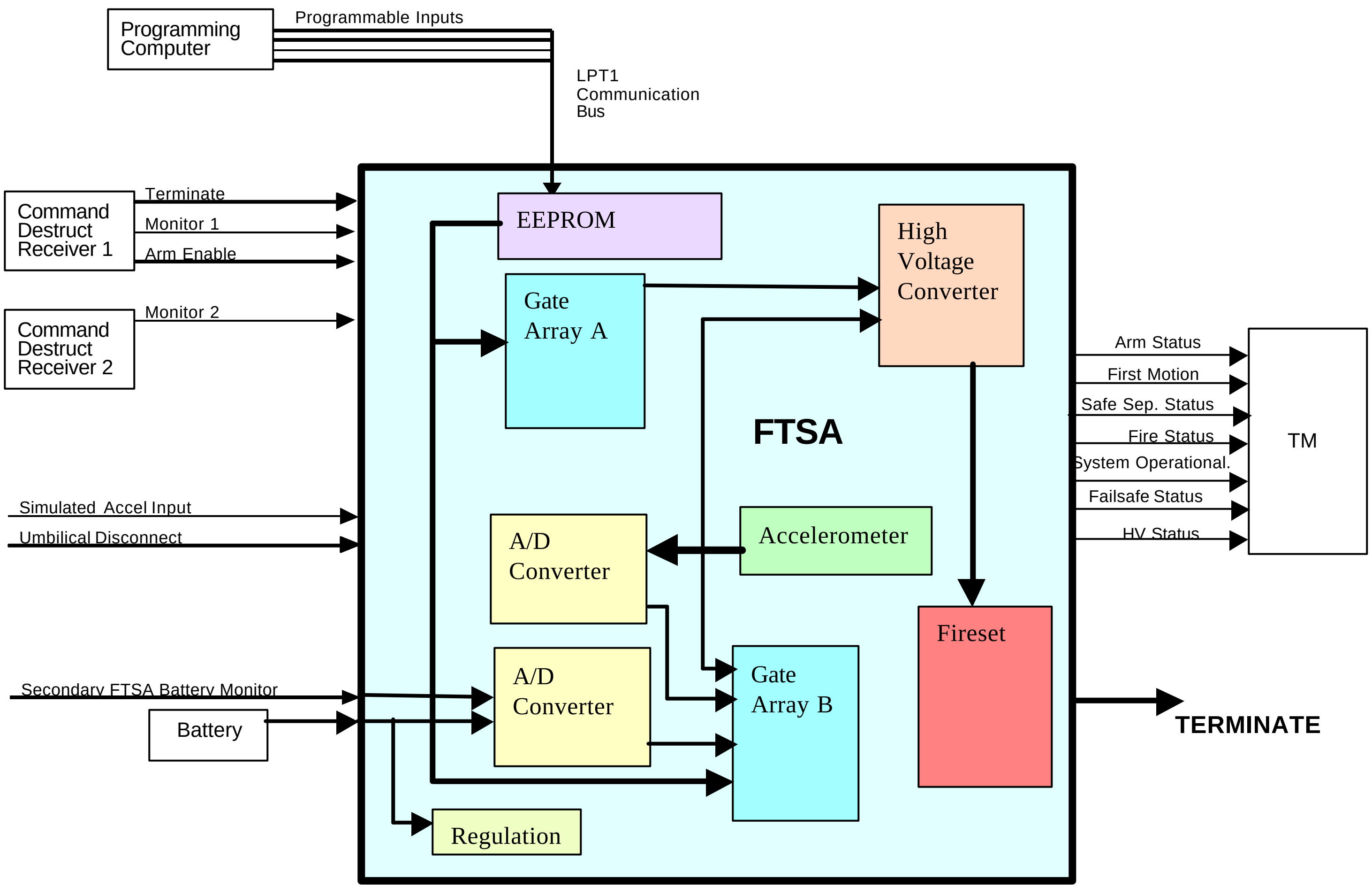
JAMI FTSA BENIFETS

- Standardization
- Off-the-shelf availability
- Low Unit Cost
- Small Size & Weight

JAMI FTSA Requirements

- Compliant With RCC 319-99
- Programmable For Multiple Applications (at test facility)
- Small Size (< 9 in^3/unit)
- Low Cost (~$2000/unit)
- Qualified To "Worst Case" Environmental Levels
  - Based on Environments of Potential Users
- Removable Explosives (LEEFI, Etc.)
- Fully Testable (Including HV Output)

Block Diagram of JAMI FTSA



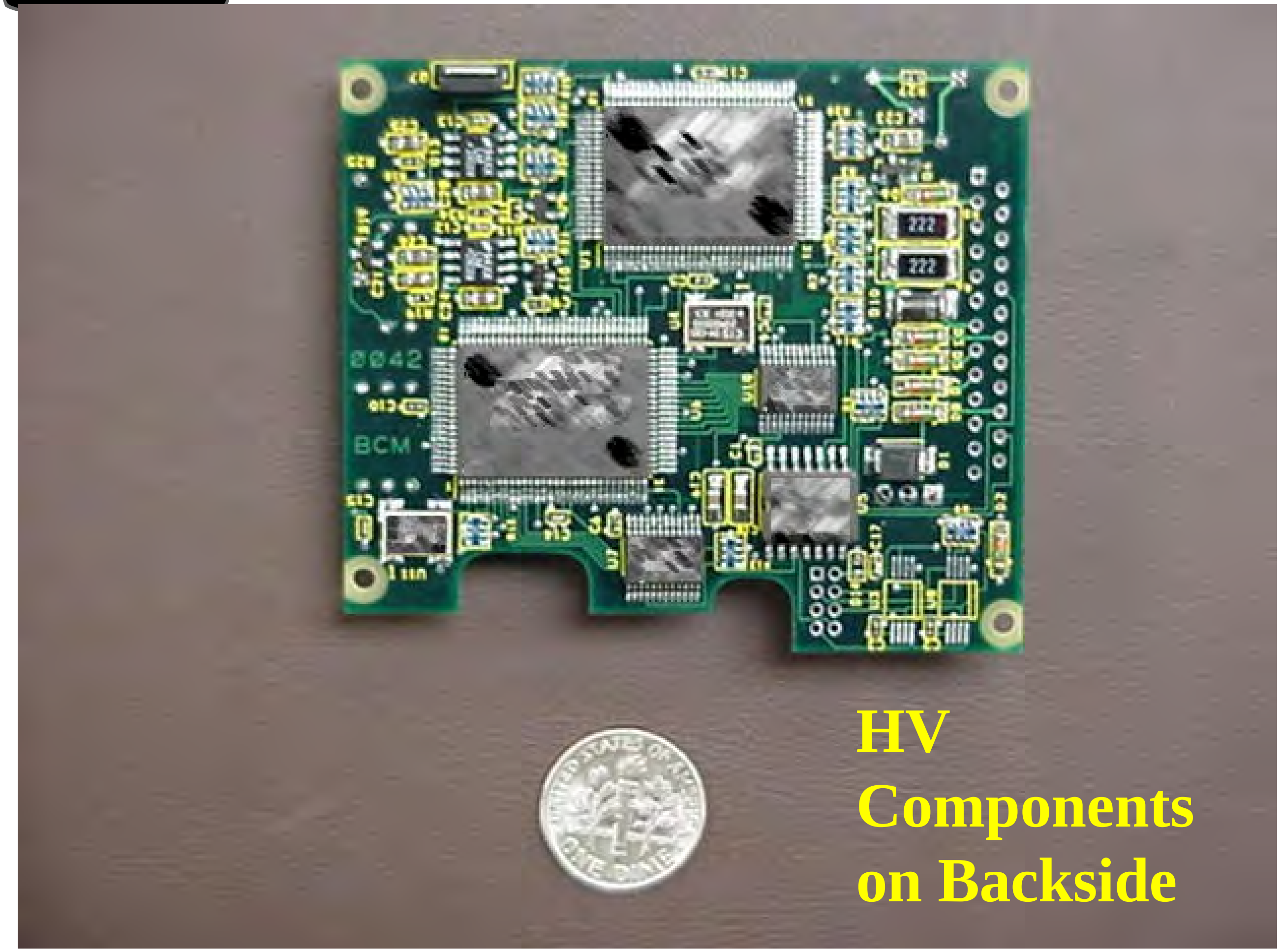
INPUTS & OUTPUTS

- **Programmable Inputs**
  - **Failsafe Enable**
    - **Loss of Monitor (tone)**
    - **Loss of Power**
  - **First Motion Enable**
    - **First Motion Valid Time**
  - **Acceleration Enable**
    - **Axis of Acceleration**
    - **Acceleration Level**
  - **Umbilical Disconnect Enable**
  - **Safe Separation Time**
  - **Arm Enable**
- **Non-Programmable**
  - **Terminate Command**

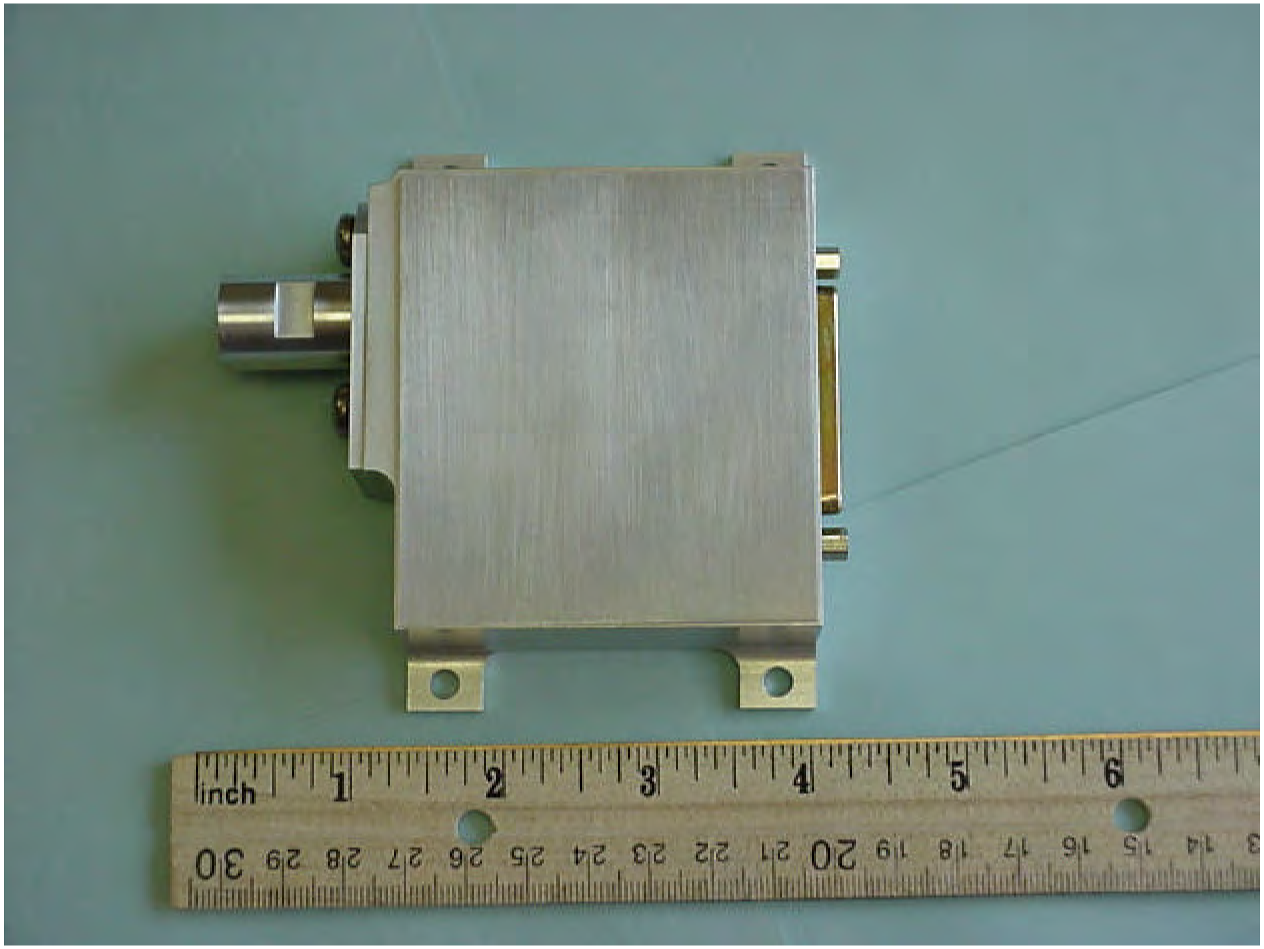
•OUPUTS

- **Flight Destruct (Explosive)**
- **Safe/Arm Status**
- **Fire Status**
- **Safe Separation Status**
- **First Motion Status**
- **System Operational**
- **Failsafe Status**

Logic Circuits

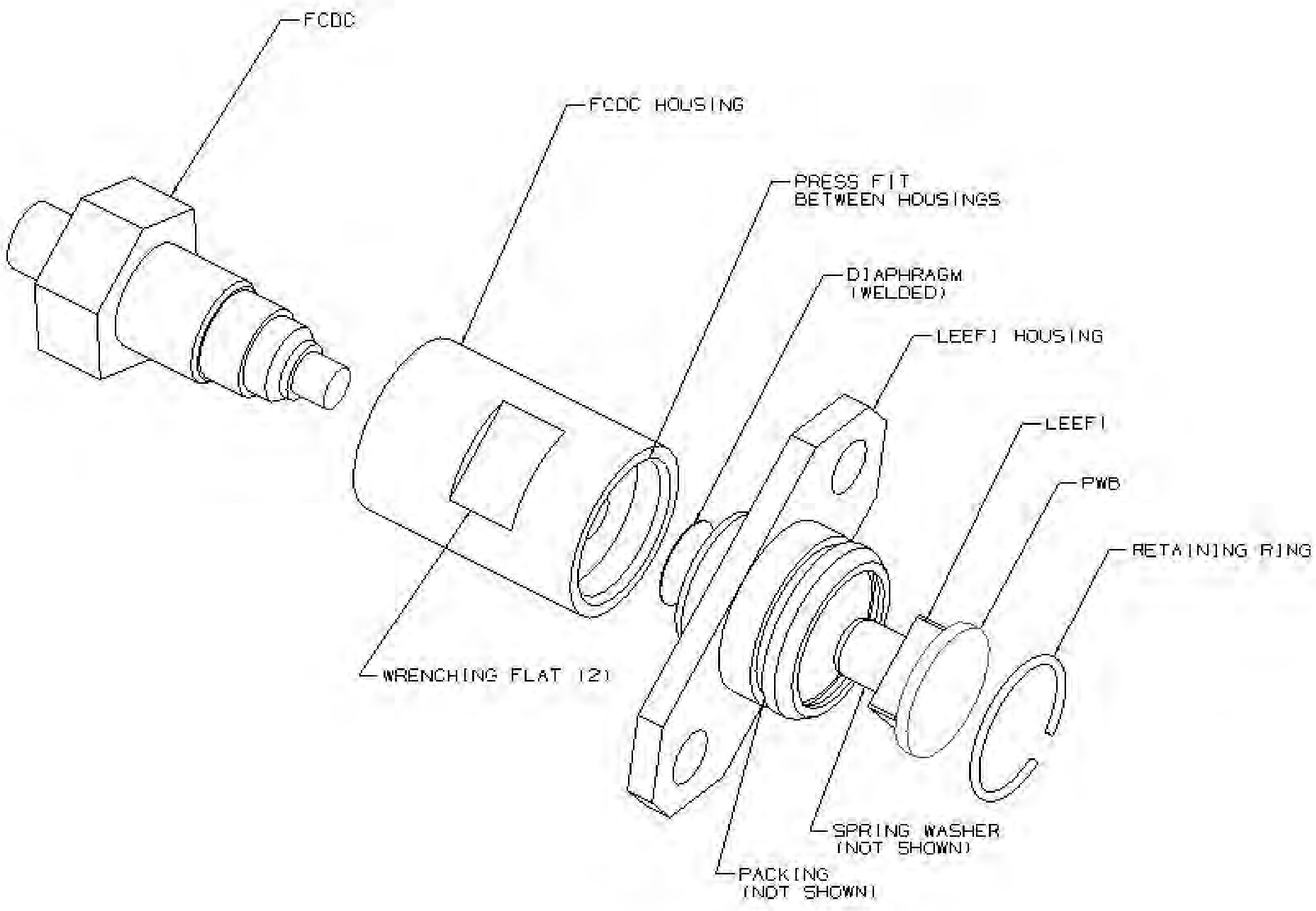


FTSA Housing Model



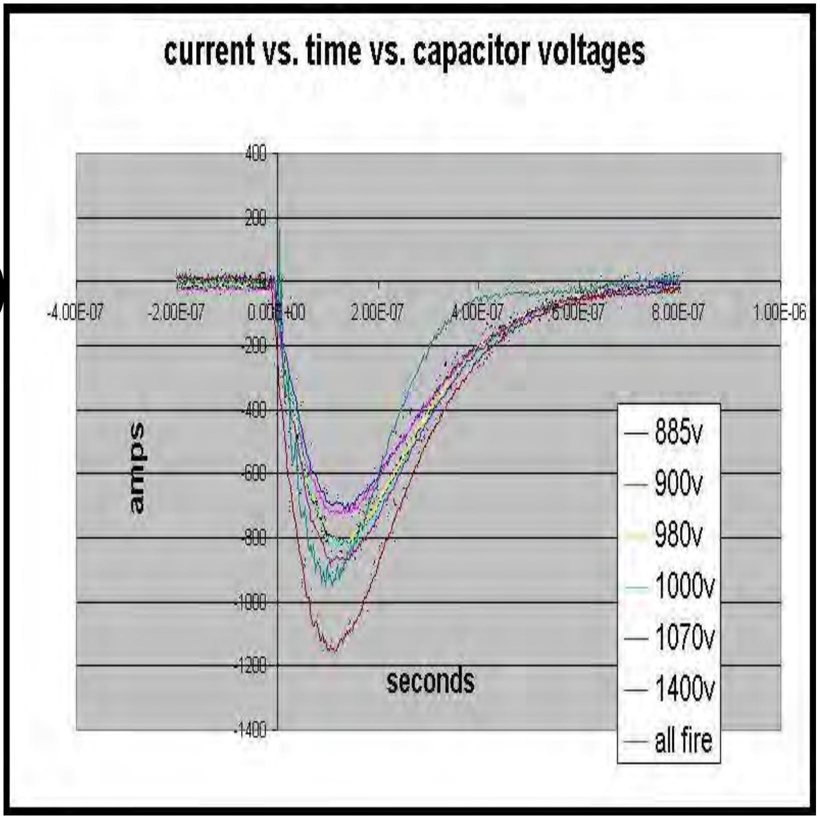
KAMAN

FCDC Components



JAMI FTSA FIRESET

- Novel Design
- Small In Size
- Low In Cost (<$20)
- High Reliability
  – 3200 shots @ 1500A
- No Unique Parts
  – All COTS



TEST ENVIRONMENTS

- Range Safety Document RCC 319-99
  - May be First FTSA Fully Qualified to New Document

- Database of Environmental Profiles of Numerous Weapons Systems

STATUS

- **Specification Completed**
- **Housing Design Complete**
- **FCDC Interface Complete**
- **Electrical Design Complete**
- **Prototype Board built and tested**
- **Fireset Studies Complete**
- **Pre-production**
  - **Design Update in final stage**
  - **Boards planned**
  - **Pre-Qualification tests to be run to find “weak points”**
  - **Expect Qualification Completion Second Qtr 2002**

Developmental Testing Summary

- Fireset
- Logic Circuits
  - Functional Test of Disable Parameters
  - Programmable Time and Thresholds Verification
- Temperature Range Tests

Developmental Test Errata

- **Electrical Corrections**
  - **Q1 pins 3 & 4 Reversed**
  - **R19& R25 Resistance Value Change for Specified Threshold**
    - **47.5k to 68k**
  - **Missing Run from R21 Node 6 to node 5**
  - **Missing Pad R17**
  - **Maxim A/D MAX154 no longer std. production item**
  - **2SK2663 (HV Transistor) no longer in production.**
- **Mechanical Corrections**
  - **Component interference with Tactical Connector**
  - **Q7 on wrong side of board, through hole reverse placement**
  - **Component Height**

Design Analysis Summary

- **Tolerance**
  - **Preliminary circuit tolerance analysis performed with pre-production design**
- **Stress**
  - **Design performed with TE000-AB-GTB-010 as a guideline**
- **Fault Tree**
  - **Design performed to preclude single point failure and implement desired modes of operation.**
- **Final Analysis, including FMECA, to be completed in conjunction with pre-production evaluation testing.**

Fire Circuit Tests

- **Established All-Fire Voltage**
  - **Explosive Tests forthcoming**
- **Temperature Cycled -30°C to +92°C**
  - **Output Current degraded 5% maximum**
- **Range Safety Requirement for 50% Energy Margin Exceeded by 105 milli-joules threshold (predicted), 203 milli-joules available. Based on nominal capacitor value.**

KAMAN

Functional Verification Tests

First Motion Valid

Programmed Time	Measured Time	% Error
5 Seconds	5.017	0.3
10 Seconds	10.017	0.2
155 Seconds	154.90	0.06
160 Seconds	160.03	0.02

Safe Separation

Programmed Time	Measured Time	% Error
0.1 Seconds	0.10000	0
10 Seconds	10.2	0.19
25 Seconds	25.6	2.3

Functional Verification Tests

Loss of Power Threshold

Programmed Time	Measured Voltage	% Error
21 Volts	20.74	1.2
22 Volts	21.22	3.7
23 Volts	22.27	3.3
24 Volts	23.6	1.7
25 Volts	24.9	0.4
26 Volts	25.7	1.1
27 Volts	27.2	0.7
28 Volts	28.5	1.7

Loss of Tone

Programmed Time	Measured Time	% Error
1 Second	1.02	2.0
2 Seconds	2.04	2.0
31 Seconds	31.7	2.2
32 Seconds	32.79	2.4

Plans

- **Qualification Plan in Process**
- **Number of units under CRADA is 12**
  - **2 Pre-qualification Engineering**
  - **10 Range Qualification Units**

MILESTONE	00	01	02	03
• Prototype built & tested….D	D			
• Pre-production boards ……..D built and tested		D		
• CDR……………………………D		D		
• Qualification Hardware built…D		D		
• Qualification……………………..D			D	

FTSA Feedback

- Your Comments, Questions or Concerns

Spin Rate Sensor for Fuzing Applications, Theory and Test Results

Presented by: Dale Spencer, Kaman

Co-Authors:

Tim Tiernan, TPL Inc.

Pete Solari, Kaman

Fred Piering, Dayron

Sponsor: W. Konick, ARDEC

Overview

- Theory
  - Magnetic Field Sensor
  - Application
- Test
  - Methodology
  - Hardware
  - Set Up
  - Results
- Conclusions
- What's Next

Roles

- Army Sponsor
  - **Ultra Sensitive Integrated Magnetic Field Sensors For Fuze Applications, Army Contract Number: DAAE30-99-C-1068**
- TPL, Inc **SBIR Phase II Contactor--** Sensor
  - Kaman Subcontractor – Data Recorder and Packaging
  - Dayron -- 40 mm projectile, Range, Test

Spin Rate Sensor Test Team

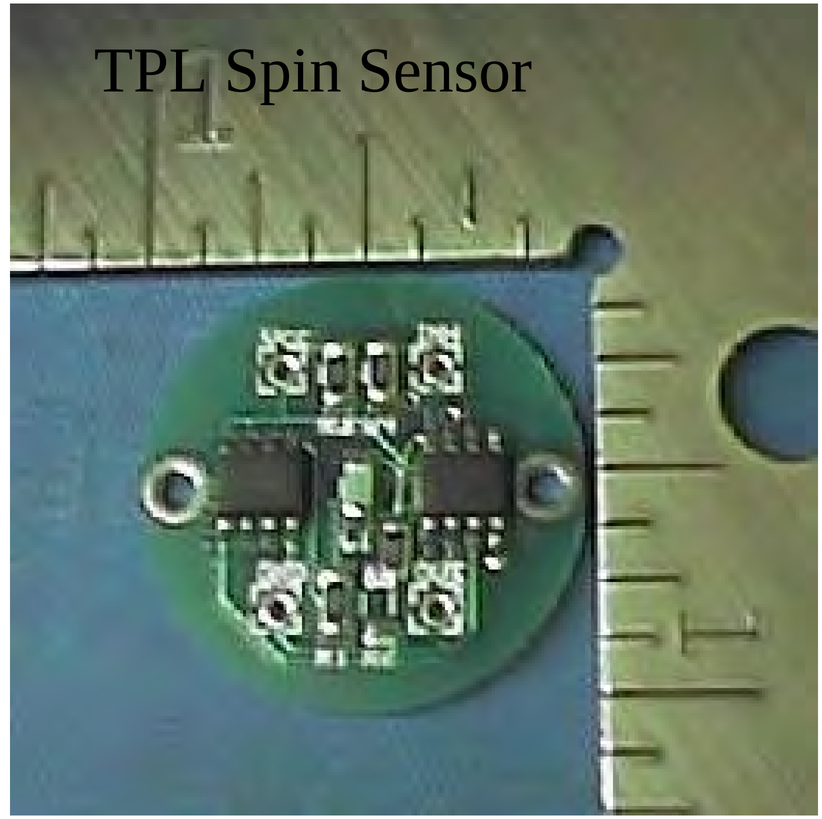
Dale Spencer , Tim Tiernan ,William Konick, Carlos Tessonniere, Jim Nasternak , Kenny LaClair , Wes Sprouse , Pete Solari

Theory -- Magnetic Sensor

- Giant Magnetoresistive material.
- The sensor can detect the ambient magnetic field of the earth with a high signal to noise ratio.
- The response of a GMR sensor is strongly related to its orientation with respect to a magnetic field.
- As the munition spins,
  - the sensor mounted inside changes direction with respect to the earth's magnetic field.
  - a sinusoidal waveform is output by the sensor as it moves from alignment to disalignment with the earth's magnetic field with each revolution of the munition.

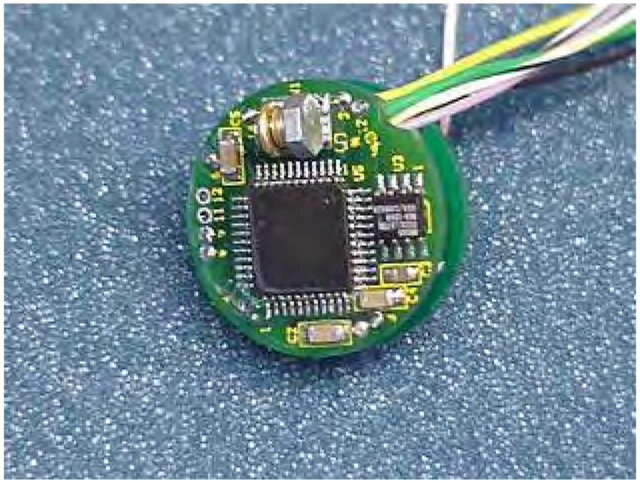
Theory Applied

- Application Theory Developed by TPL, Inc
  - Resolve shell dynamic rotations
  - Rotations for fixed rifling equal distance
  - Multiply rotations to obtain distance



Test Methodology

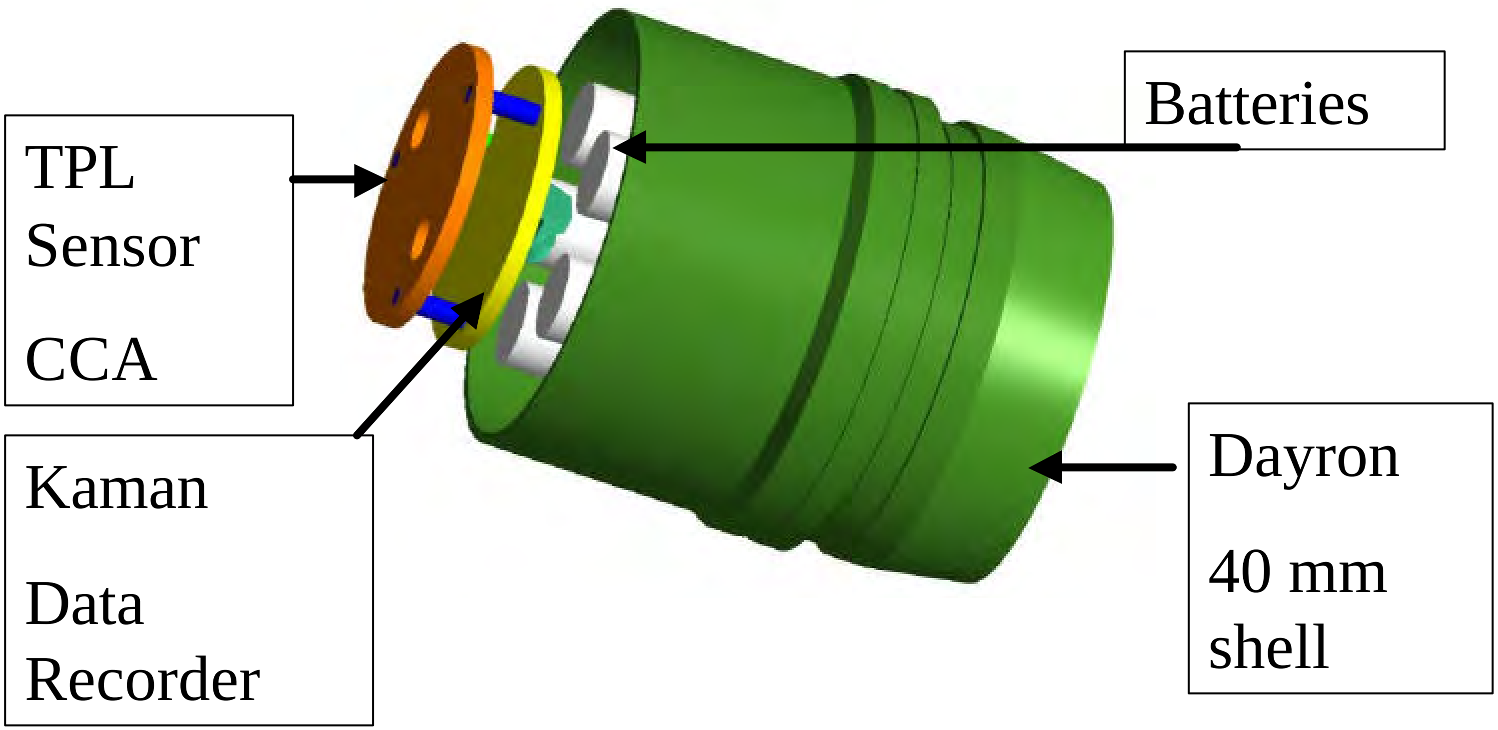
- Dynamic Firing Test
  - Validate Theory through live fire demonstration
  - Build Sensor
  - Integrate Sensor and Data Recorder into projectile.
  - Fire Projectile in Gun with known rifling
  - Measure projectile velocity
  - Compare Projectile turns per second with velocity



KAMAN Data Recorder

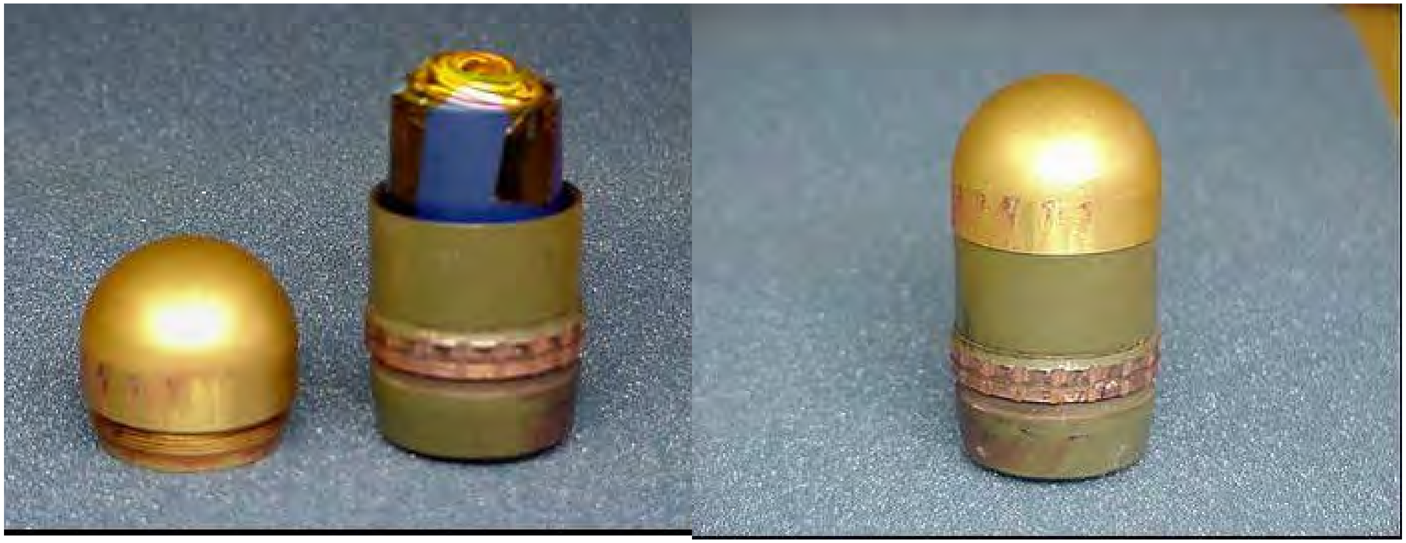
Integrated with TPL Spin Sensor

Conceptual Package for Test



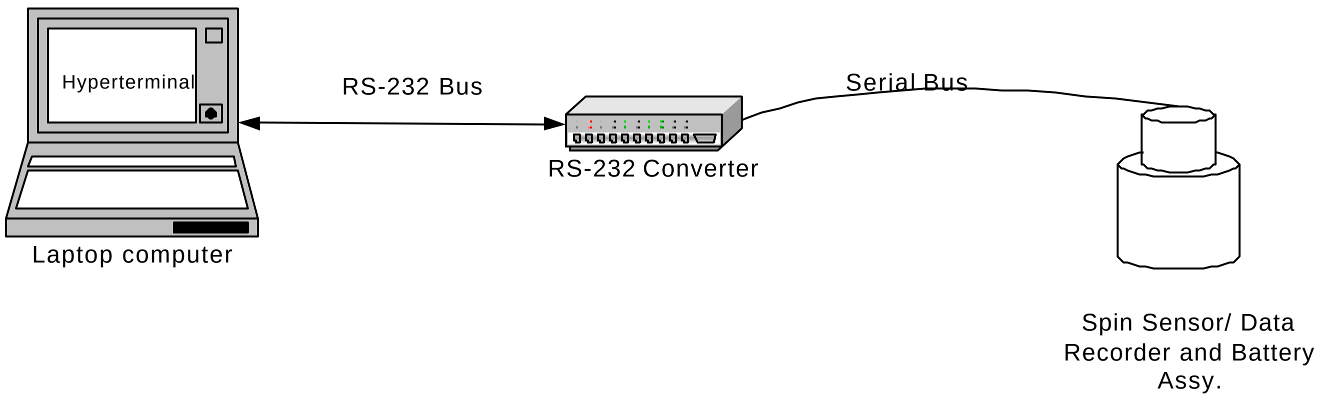
3-D Packaging by R. Spooner, Kaman

Test Projectiles



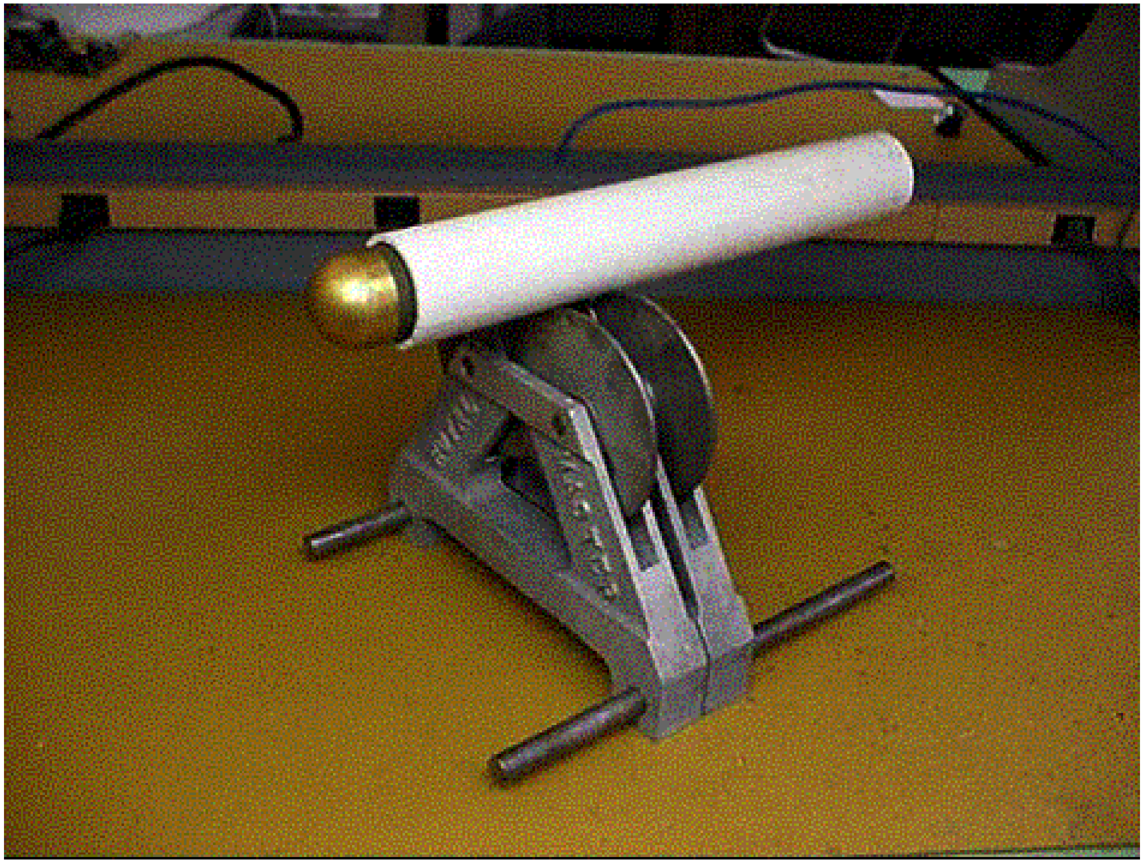
Note: Rifling Grooves, this projectile has been fired and recovered

Data Interface

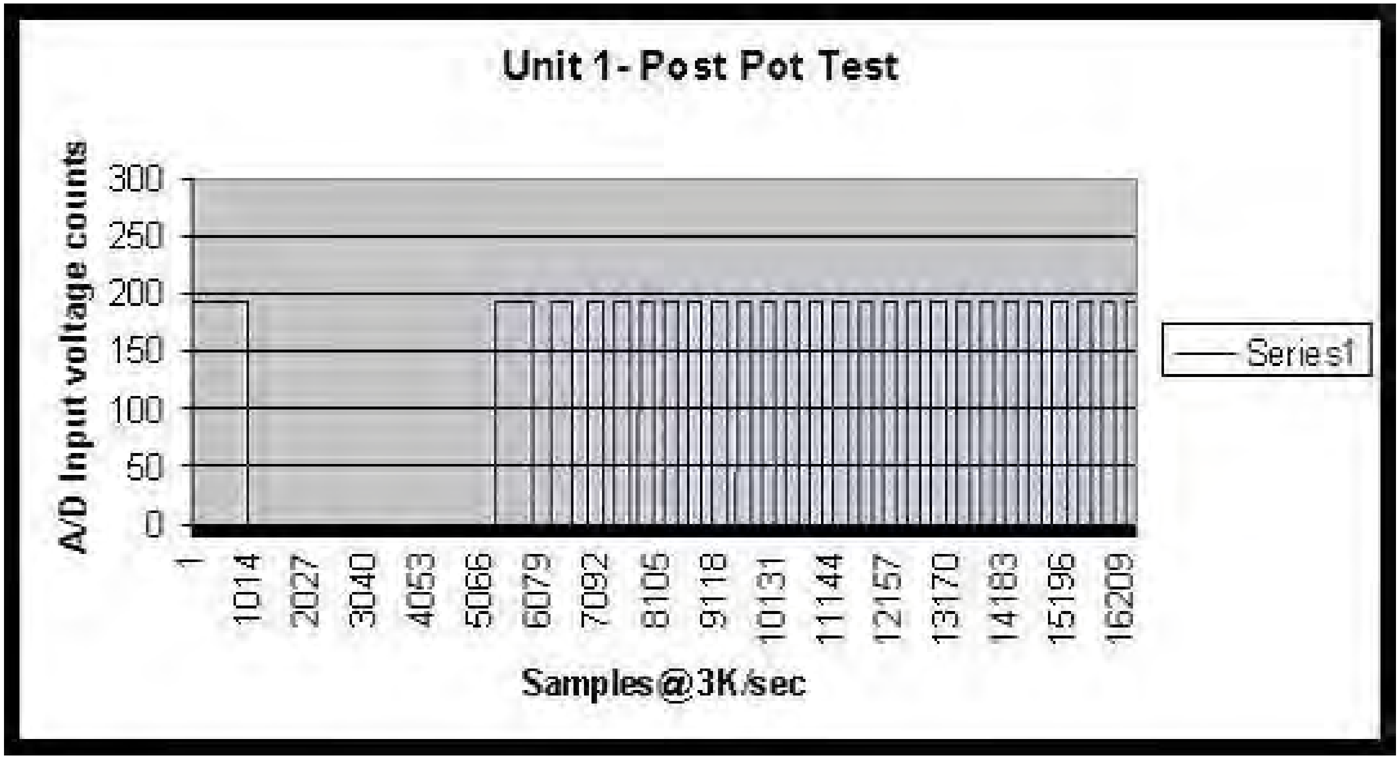


- **PC Running Hyperterminal**
- **Arming Parameters Set Via RS-232 Port**
- **Data Downloadable To PC's Via RS-232 Port**
- **All Code Embedded in Recorder**
- **No peculiar PC software**

Bench Test



Bench Test

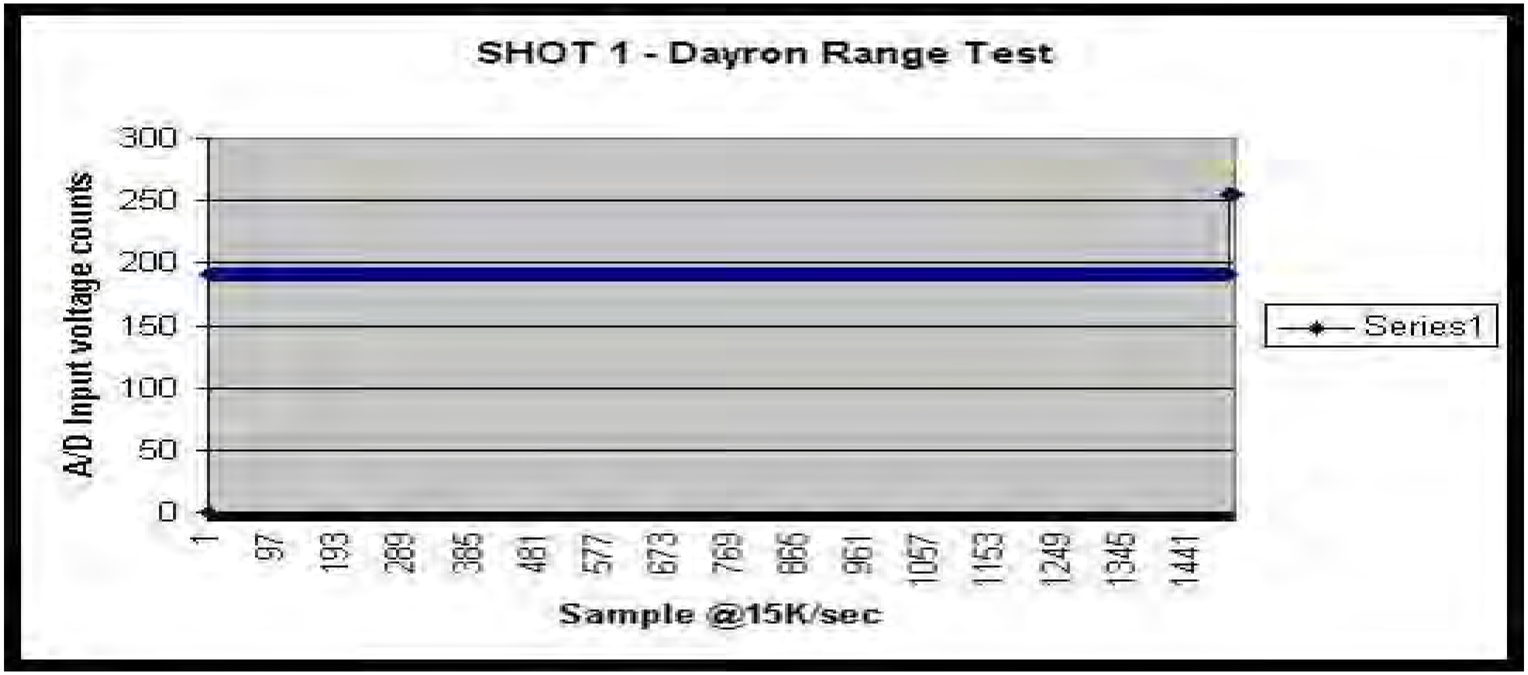


Spin up rate as expected

Transition from low to high as expected

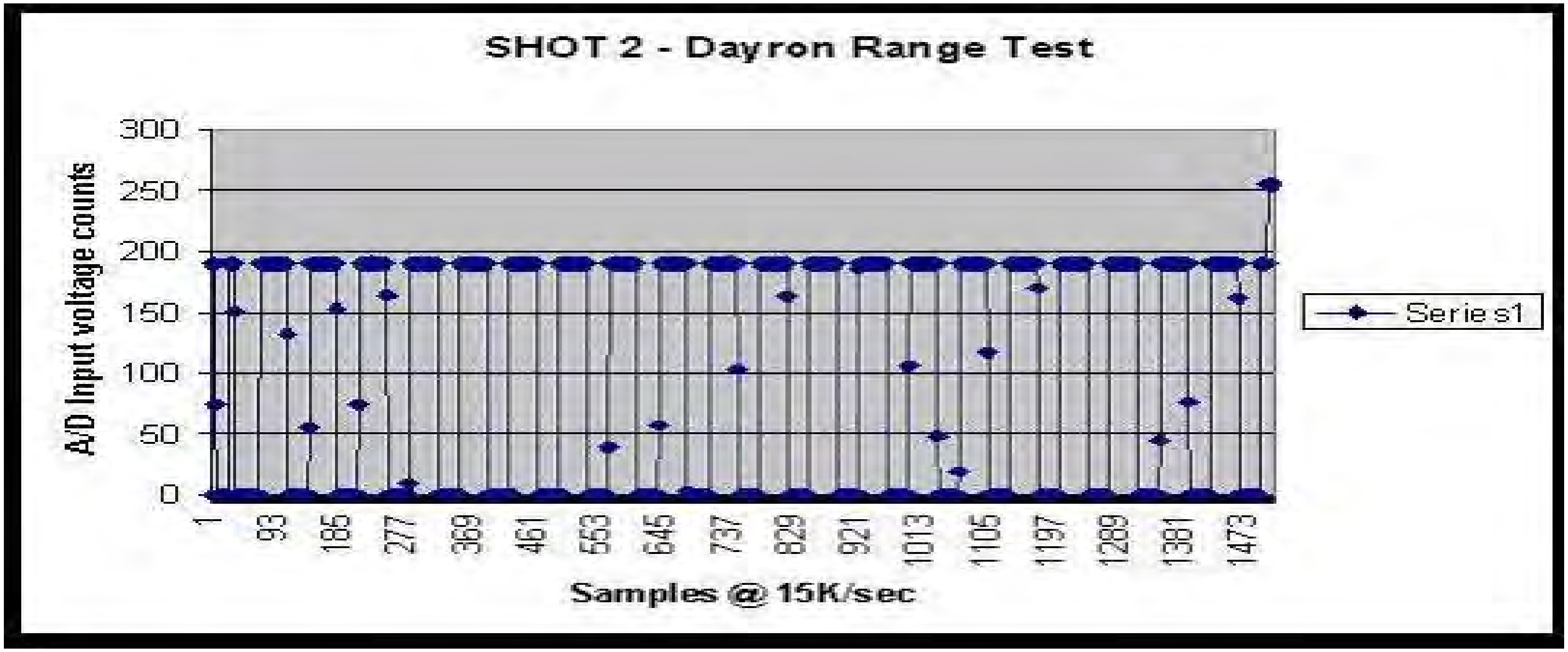
Test Range

Shot # 1 Results



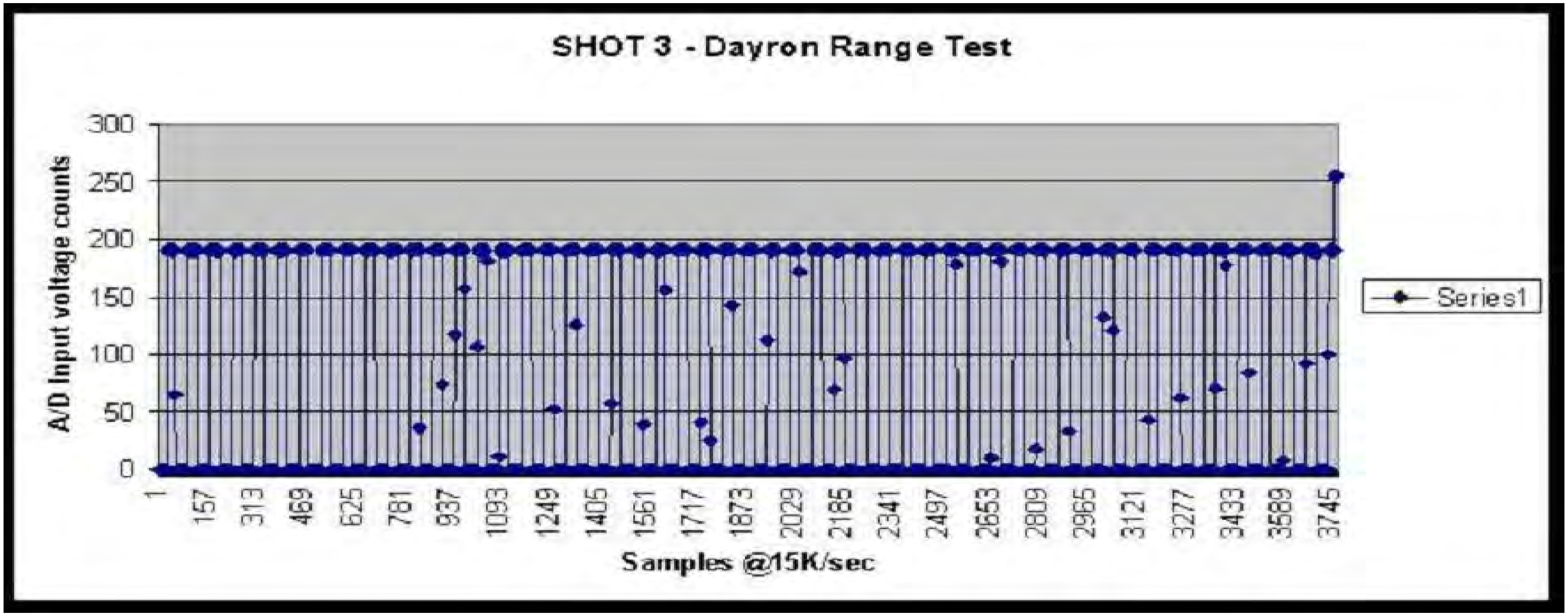
- Flat Line Indicated Problem in First Test
  - First Bit Low and Last High Indicated Recorder OK
  - Digital Value Corresponded to Saturation

Shot # 2 Results



- Interesting Data
  - Calculated velocity higher than expected
  - Decide to measure velocity with laser diode velocimeter for next shot

Test Shot #3



- Good Data
- Measured Velocity = Spin Rate Velocity < 1% error

Test Results

Shot #3	Measured Muzzle Exit Velocity (ft/sec)	Weight (lb)	Number of Turns	Predicted Flight Distance @ 0.25sec Flight Time (ft)	Turns Calculated Flight Distance (ft)	Error (%)
Dayron Round	813	0.740		203.25		
SR Round	831	0.722	51.5	207.75	206.00	0.84

Predicted Flight Distance == Muzzle Velocity * Flight Time = 831 * 0.25 = 207.75 ft

Turns Calculated Flight Distance = # of Turns * 4 ft/Turn = 51.5* 4 = 206.0 ft

% Error = ((Predicted Flight Distance - Turns Calculated Flight Distance) / Predicted Flight Distance) * 100 = ((207.75 - 206)/207.75) * 100% = 0.84%

Conclusions

- Test was a success
- Sensor capable of resolving spin rate accurately
- Sensor is survivable and working immediately upon exit from barrel
- Recorder is survivable and working prior to exit from gun barrel

Design Methodology for Safe & Arm Devices

Dipl.-Phys. Friedrich Sauerländer

Who am I?

NAWC WPNS
Ordnance Systems Division
China Lake, CA

BWB
WF I 5
Koblenz, Germany

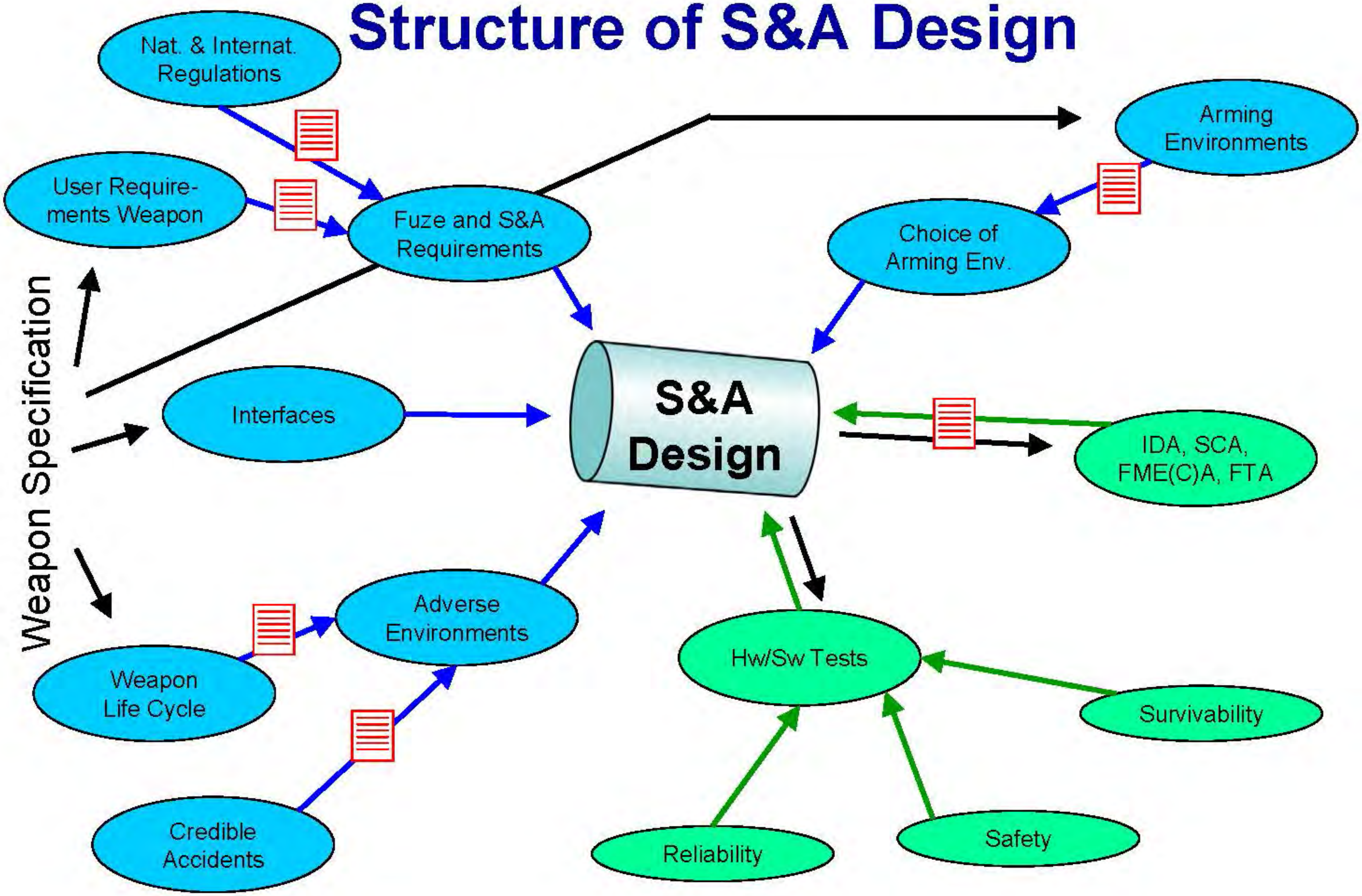
Outline

- **S&A Development Process**
  - Steps to a safe S&A
- **Fault Tree Analysis**
  - How to do it right

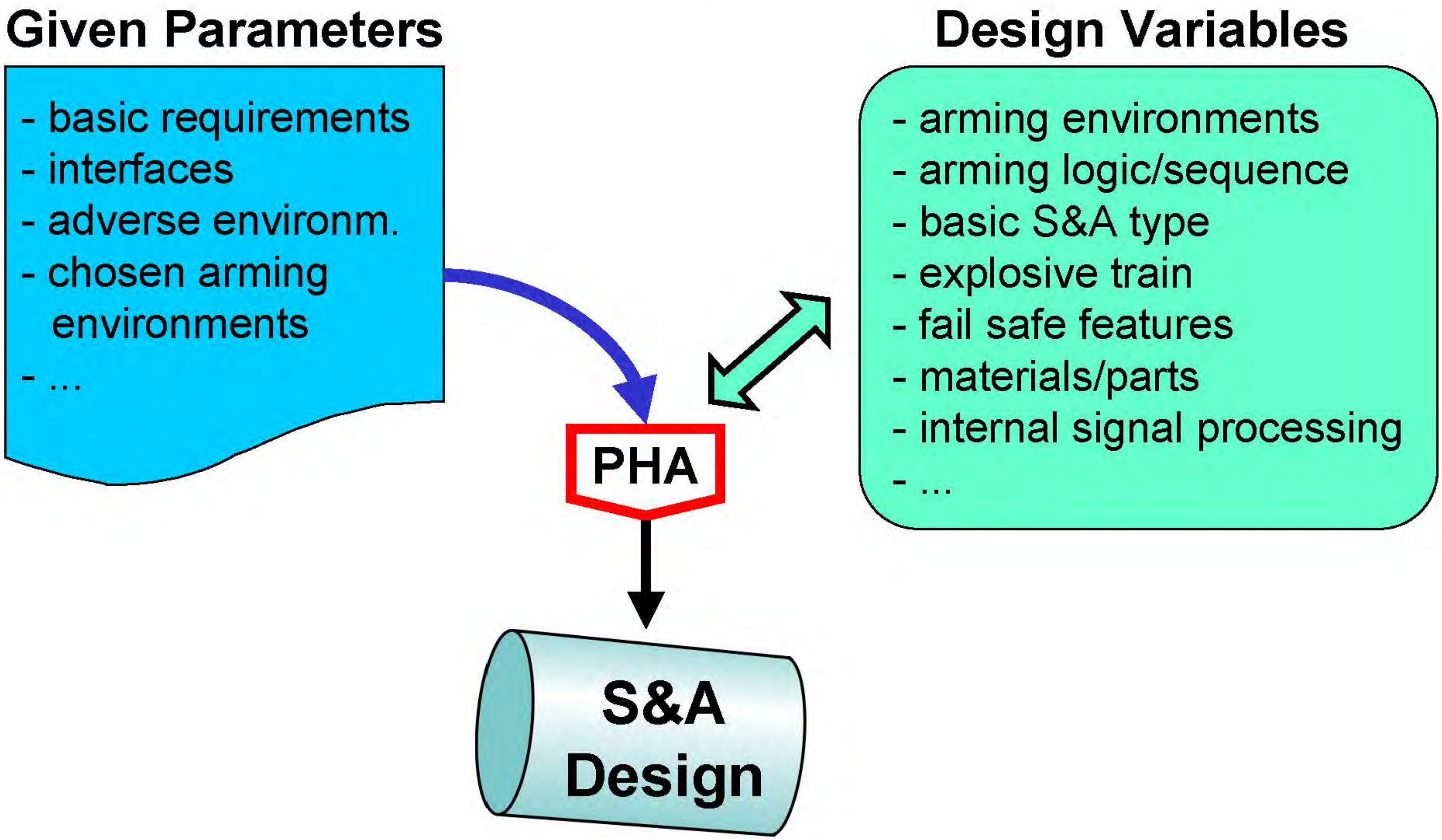
Full Report available from: FowlerSE@navair.navy.mil

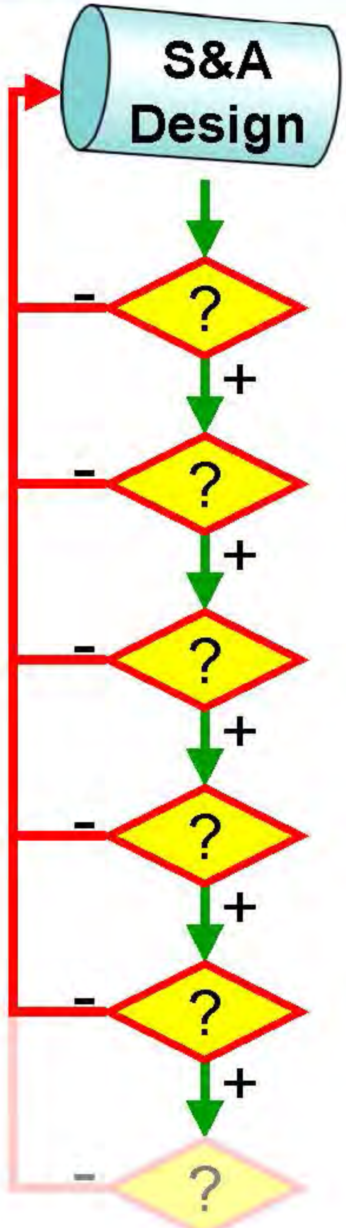
Where to start?

Structure of S&A Design



S&A Design Process

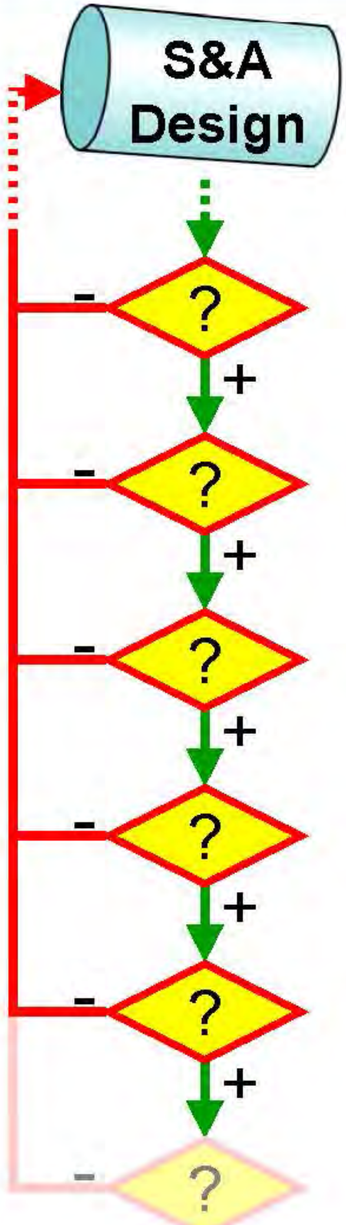




S&A Design Process

1) Design can be simplified
2) Design is fail safe
3) Preliminary FTA
4) Hazard Analysis
5) Sneak Circuit Analysis
6) …

S&A Design Process



6) Producability

7) Integrated Design Analysis (OL tree, …)

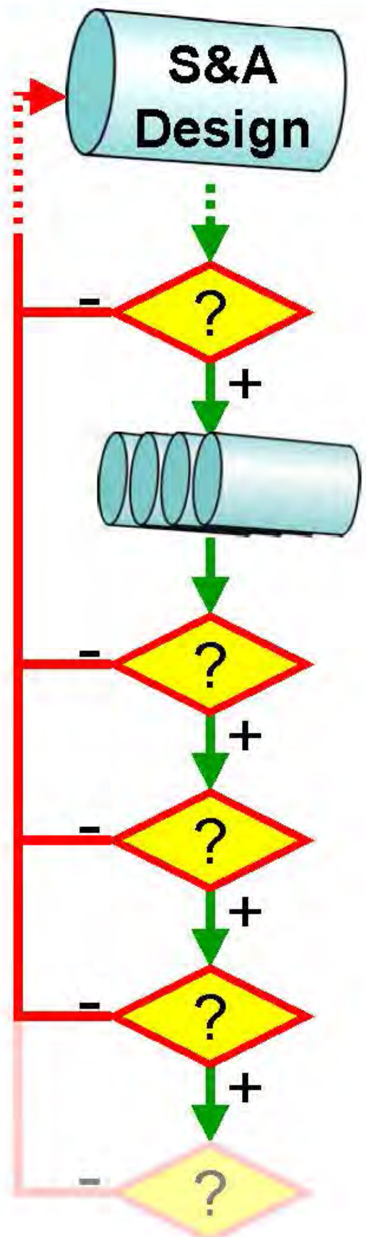
8) FME(C)A

9) FTA

10) Reliability

11) …

S&A Design Process



11) Component Tests

Production of Test Samples

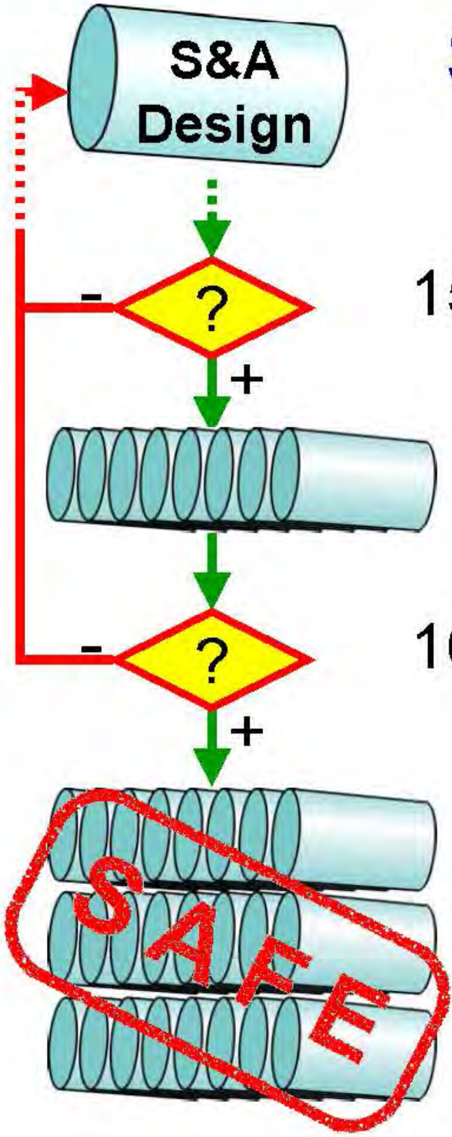
12) Function Tests

13) Qualification Level Tests

14) Test to Failure

15) ...

S&A Design Process



15) **Qualification**

Limited Production

16) User Operational Tests

Full Production

Outline

- **S&A Development Process** ✓

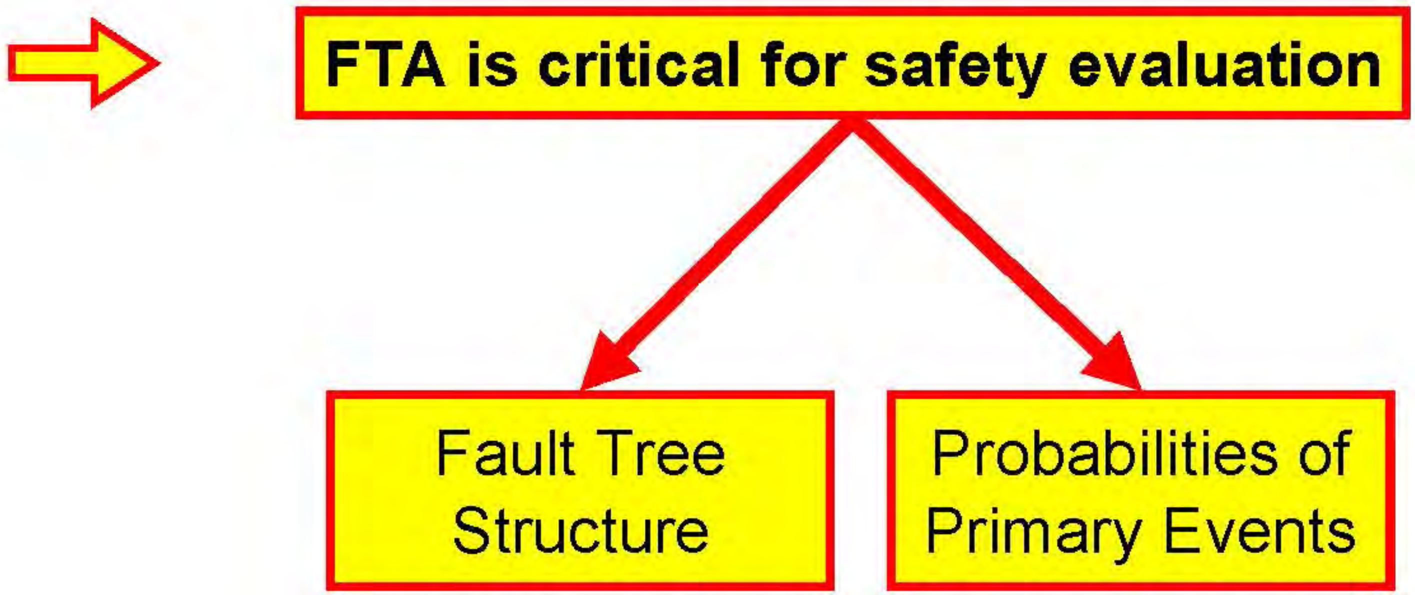
  - Steps to a safe S&A

- **Fault Tree Analysis**

  - How to do it right

Fault Tree Analysis

- FTA is basis for quantification of risk (target: $1:10^6$)



FTA - Tree Structure

- top events are Premature Arming and Early Burst
- the Fault Tree must be build on and verified at least against:
  - (P)HA
  - FME(C)A
  - drawings & schematics
  - Operation Logic Tree (from IDA)
  - SCA
- a FTA must include Primary, Secondary and Command Faults (e.g. credible accidents, errors during manufacture)

FTA - Tree Structure

- the Fault Tree should be developed into a level, where every fault from the FME(C)A and other analyses is mentioned
- subsequent deletion of limbs must be mentioned and explained

FTA - Quantitative Analysis

- provide the origin of all used data, scaling factors and expressions and explain, why they are applicable
- provide all raw data necessary to duplicate the analysis (e.g. type component, failure rate, quality level, environmental factors)
- **for ESAD** the following standard sources of failure rates should be used (as of 04/2001)

  - EPRD-97
  - NPRD-95
  - NONOP-1
  - MIL-HDBK 217(F)

FTA - Quantitative Analysis

• pooling of data:

if - for a part only a limit of failure rate is given ("> …")

and - for similar parts the failure rates are well defined,

the following expression may be used for pooling (EPRD-97):

$$\lambda_{pool} = \left(\prod_{i=1}^{n'} \lambda'_i \right)^{\frac{1}{n'}} \cdot \left(\frac{\sum_{i=1}^{n'} h'_i}{\sum_{i=1}^{n} h_i} \right)$$

λ_{pool}:	resultant failure rate
λ'_i:	failure rate of part i with failure
h_i:	time of part i
h'_i:	time of part i with failure
n:	pooled parts
n':	pooled parts with failure

FTA - Quantitative Analysis

- apply a <u>safety factor of 5</u> to all probabilities (to compensate for statistical uncertainties and deviations of actual parts)
- probability of failure is accumulated over all phases of weapon life cycle
    - storage (ground, field, mobile,…); Σ = 20 years
    - logistic transportation
    - mounted on weapon or A/C carriage
    - launch & flight/fall

$$P(\lambda, t) = \sum_i \lambda_i \cdot t_i$$

P : probability of failure
λ_i : failure rate in environment i
$\lambda_i = MTBF_i^{-1}$
t_i : duration of environment i

FTA - Quantitative Analysis

Example 1:

Electronic part, highly reliable but sensitive to environment

Environment	Time	λ [10^{-6}/h]	$P(\lambda,t)$	%
Ground Storage (GB)	20 yrs. = 170,265 h	0.001	$1.7 * 10^{-4}$	53
Field Storage (GF)	6 months = 4,383 h	0.01	$4.4 * 10^{-5}$	14
Transportation (GM)	21 days = 504 h	0.05	$2.5 * 10^{-5}$	8
A/C carriage (AUF)	7 days = 168 h	0.5	$8.4 * 10^{-5}$	26
Launch & Flight (ML)	120 s = 1/30 h	5	$1.7 * 10^{-7}$	0.05
			$3.2 * 10^{-4}$	

FTA - Quantitative Analysis

Example 2:

Electronic part, less reliable, less sensitive to environment

Environment	Time	λ [10^{-6}/h]	P(λ,t)	%
Ground Storage (GB)	20 yrs. = 170,265 h	0.05	$8.5 * 10^{-3}$	92
Field Storage (GF)	6 months = 4,383 h	0.1	$4.4 * 10^{-4}$	5
Transportation (GM)	21 days = 504 h	0.2	$1.0 * 10^{-4}$	1.1
A/C carriage (AUF)	7 days = 168 h	0.8	$1.3 * 10^{-4}$	1.5
Launch & Flight (ML)	120 s = 1/30 h	2	$6.7 * 10^{-8}$	0.001
			$9.2 * 10^{-3}$	

Conclusion

I have tried to show

- "Best Practice" Way of S&A Development
  - General Step-By-Step List

- "Best Practice" for FTA
  - highlighted points for FTA structure
  - guidelines for quantitative analysis

based on experiences in Germany, USA and with NATO AC/310, SG II.

Full Report available from: FowlerSE@navair.navy.mil

NDIA
45th Annual Fuze Conference

Design and Development of a new Electronic Time (ET) Fuze for Mortars (XM784/XM785)

18 April 2001

TACOM-ARDEC Fuze Division
Anthony Pergolizzi and Dennis Ward

XM784 / XM785
Electronic Time Fuze for Mortars

- Background
- Need
- Requirements Overview
- Programmatic Approach
- Schedule
- Technical Approach

XM784 / XM785 ET Fuze for Mortars
Background

- **No US Fielded ET Fuze for Mortars Exists**
  - **US Requirements Filled By Foreign Source**
  - **M776 / M772 Diehl/Junghans (Germany)**
    - **Under Waiver From US Safety Standards**
- **User Persistently Indicated Need For a US ET Fuze (Since Mid ’80’s)**
- **No NDI Design Solution Exists**
  - **Foreign Comparative Studies**
  - **Engineering Studies**
  - **Contractor Studies**

XM784 / XM785 ET Fuze for Mortars
Need

- **Army Safety Standards**
  - **No Current Time Fuze Meets Standards**
- **Need For Increased Timing Accuracy**
  - **Poor Fuze Accuracy**
  - **Adversely Effects Cartridge Performance**
- **Three Fuze Types**
  - **PROX: (M734A1 Multi-Option Fuze)**
  - **PD / Delay: (XM783)**
  - **Time: (XM784 (60 / 120 mm) & XM785 (81 mm))**
- **Legacy Fuzes Require a Wrench To Set**
  - **Difficult to Read**
  - **Require External Lighting**
- **Mortar Time Fuze Modernization**

XM784 / XM785 ET Fuze for Mortars

Requirements

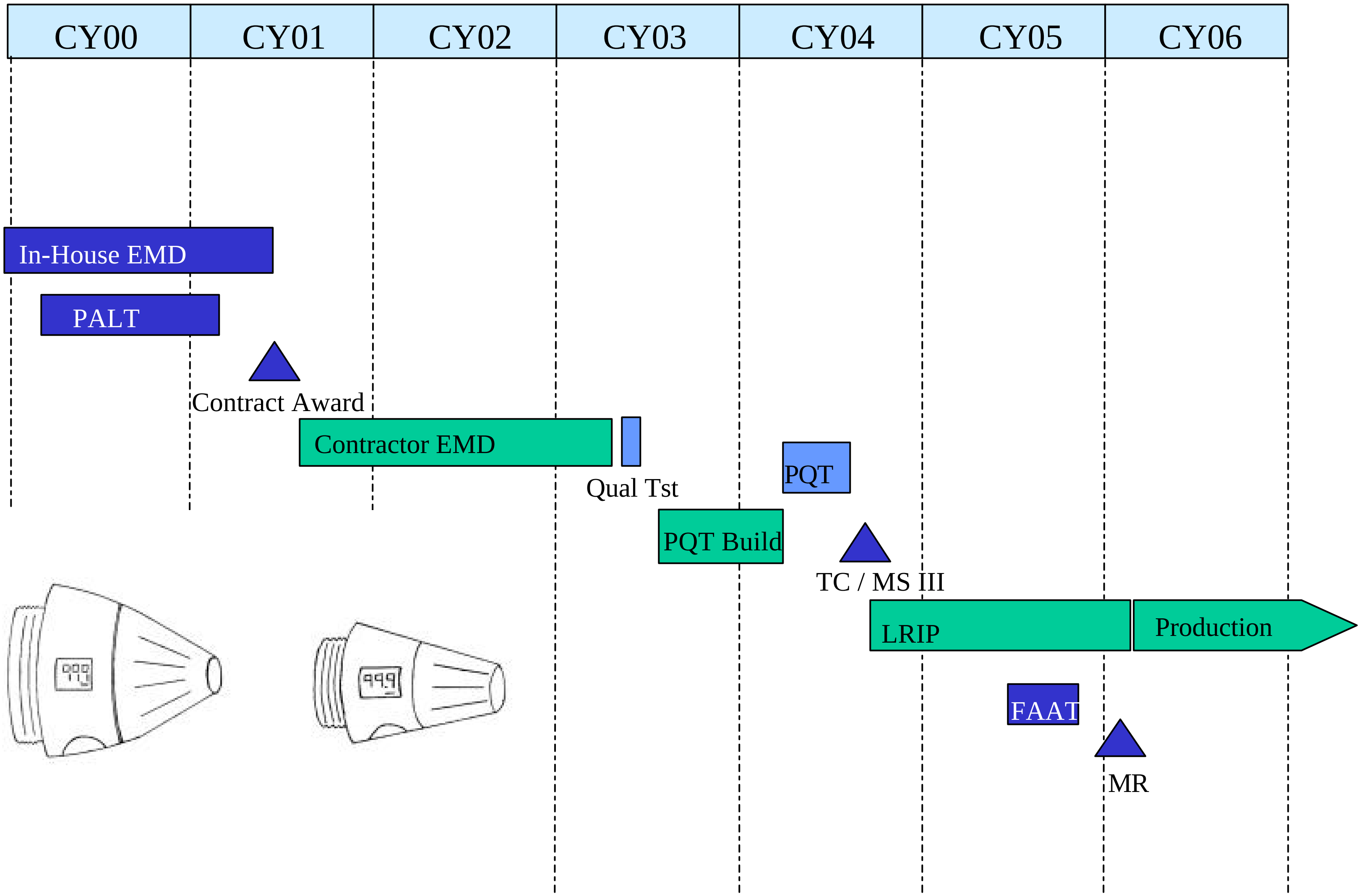
- **Safety Per MIL-STD-1316 (Dual Environ Safety)**
- **Cartridge Compatibility:**
  - **60 mm (M721 Illum & M767 IR Illum)**
  - **81 mm (M853A1 Illum, XM816 IR Illum & M819 RP Smoke)**
  - **120 mm (XM930 Illum, XM983 IR Illum)**
- **Hand Settable Required (Inductive Set Desired)**
  - **Self Illuminating**
- **Accuracy 98%**
- **Set Time 5 – 99.9 Seconds (0.1 Sec Increments)**
- **Cannot Significantly Degrade Cartridge Range**
- **20 Year Shelf Life (Controlled Environment)**

XM784 / XM785 ET Fuze for Mortars
Programmatic Approach

- Systems Engineering / IPT Approach
- Initial Gov't Eng Activity – Risk Mitigation Effort
- Solicit Contractor – Competitive / Cost Plus Type
  - Phase 1: Develop & Demo Design Solutions (Award Fee)
  - Phase 2: Production Qualification / TC (Award Fee)
    - Conduct Government Ballistic Tests
    - TC Standard
  - Phase 3: Low Rate Initial Production (Incentive Fee)
    - LRIP Effort (22k – 60k fuzes)
      - FAAT
      - Three Production Lots to MR

XM784/ XM785 ET Fuze for Mortars

Schedule



XM784/ XM785 ET Fuze for Mortars
Technical Approach

- **Maximize Use of NDI Components**
  - **Minor Modifications**
- **Initial In-House EMD**
  - **Develop Expertise For Source Selection**
  - **Development / Technology Exploration**
    - **Fuze Electronics**
    - **Power Source**
      - **Pre & Post Launch Battery Solutions**
      - **Non-Battery Solutions**
    - **Safety & Arming Device (incl 2nd Env Sensor)**
      - **Pressure Sensor**
      - **Muzzle Exit Sensor**
      - **Air Flow Sensor**
    - **Explosive Train**
    - **Packaging and Hand Setting**

XM784/ XM785 ET Fuze for Mortars
Electronics

- **Developed a power budget**
- **Evaluated the tradeoffs of an ASIC vs a microcontroller**
- **Designed and fabricated generic surface mount breadboard**
- **Uses a lithium reserve battery (M762 style)**
- **Developed schematic diagrams, safety logic, flow charts, and block diagrams have been developed**
- **Uses an inertial "T_0" switch and impact sensor**
- **Developed logic software for the main and safety microcontrollers**
- **Interfaced the logic software with the breadboard and conducted bench tests**

XM784/ XM785 ET Fuze for Mortars
Power Supply

- **Studied candidate solutions:**

Electro-chemical	**Non-chemical**
M80	**Piezo-electric**
SD Fuze	**Electro-magnetic**
OICW	**Setback generator**
M762	**Fluidic generator**
Active lithium	**Turbine alternator**
thermal	

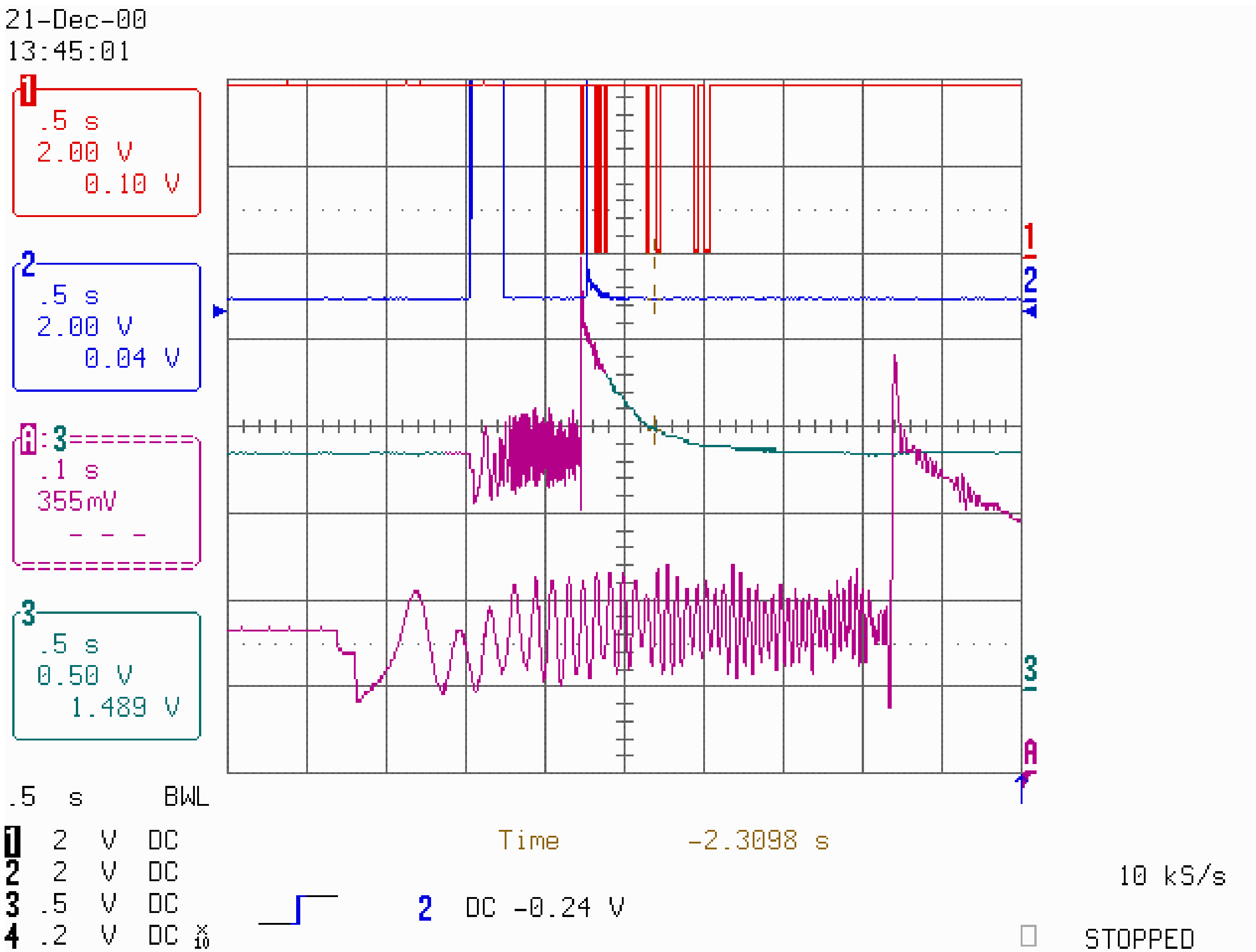
- **Capacitor cost / performance trade-offs may prohibit non-chemical initiatives**
- **Evaluated both an Evans Capattery and M762 battery for operation with our circuit**

XM784/ XM785 ET Fuze for Mortars
Second Environment Sensor

- **Researched several approaches:**
  - **Pressure / Force**
  - **Muzzle Exit (Mag, ESS, RF)**
  - **Air Flow (Turbine driven lock)**
- **Conducted RF sensor free fall drop tests**
  - **60mm, 81mm and 120mm tubes**
- **Generated pressure profile plots**
- **Adapted a COTS pressure sensor**
  - **Evaluated via laboratory flow-controller tests**
- **Conducted aeroballistic tests in wind tunnel**

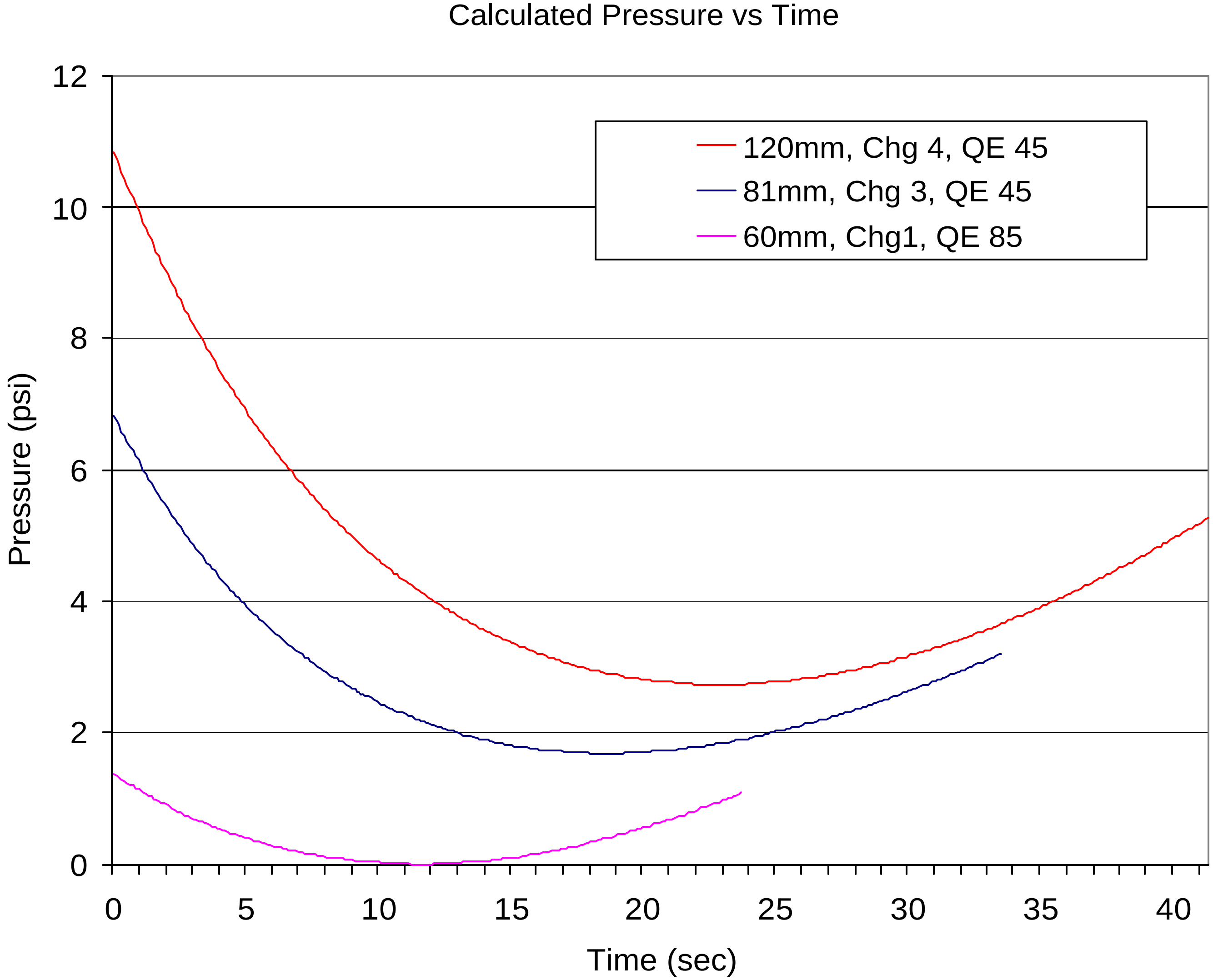
XM784/ XM785 ET Fuze for Mortars

Second Environment Sensor



XM784/ XM785 ET Fuze for Mortars

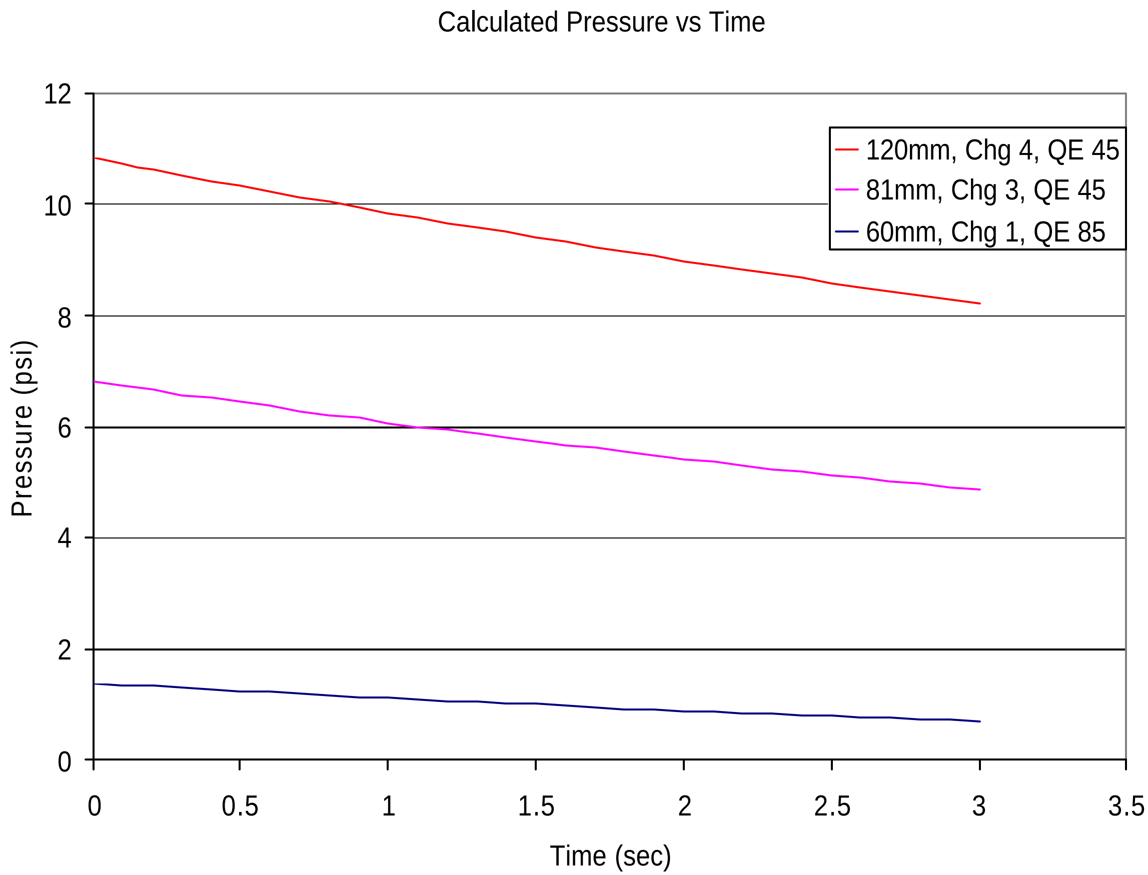
Second Env Sensor



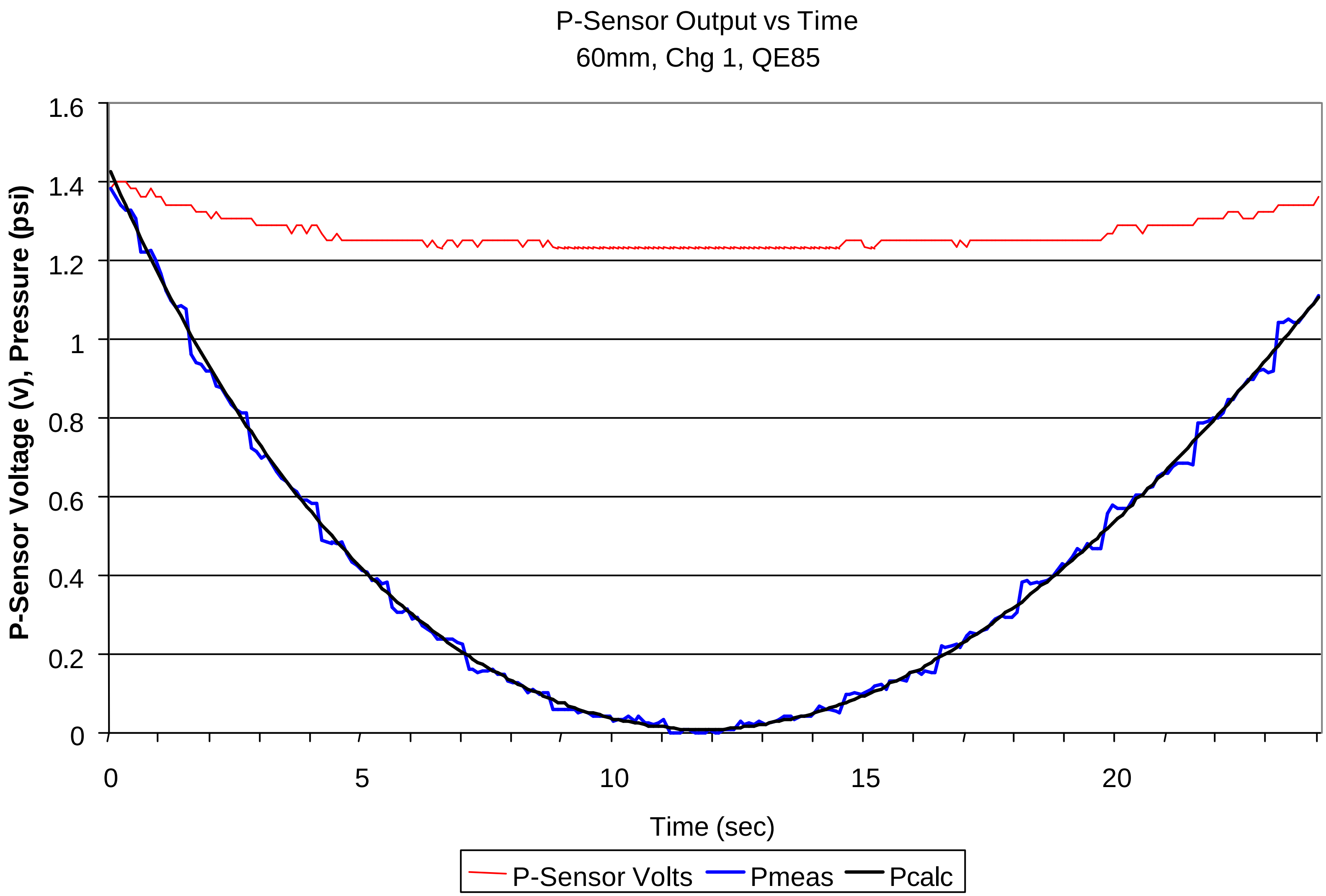
XM784/ XM785 ET Fuze for Mortars
Second Env Sensor

(Calculated Pressure - First 3 secs of Flight)

	Chg @ QE45	Press Range (psi)
	1	1.4 - 0.9
60mm	2	2.7 - 1.7
	3	4.2 - 2.7
	4	5.8 - 3.7
	1	2.1 - 1.4
81mm	2	4.2 - 3.0
	3	6.8 - 4.8
	4	9.7 - 6.8
	1	2.5 - 1.8
120mm	2	4.7 - 3.5
	3	7.4 - 5.6
	4	10.8 - 8.2



XM784/ XM785 ET Fuze for Mortars
Second Env Sensor

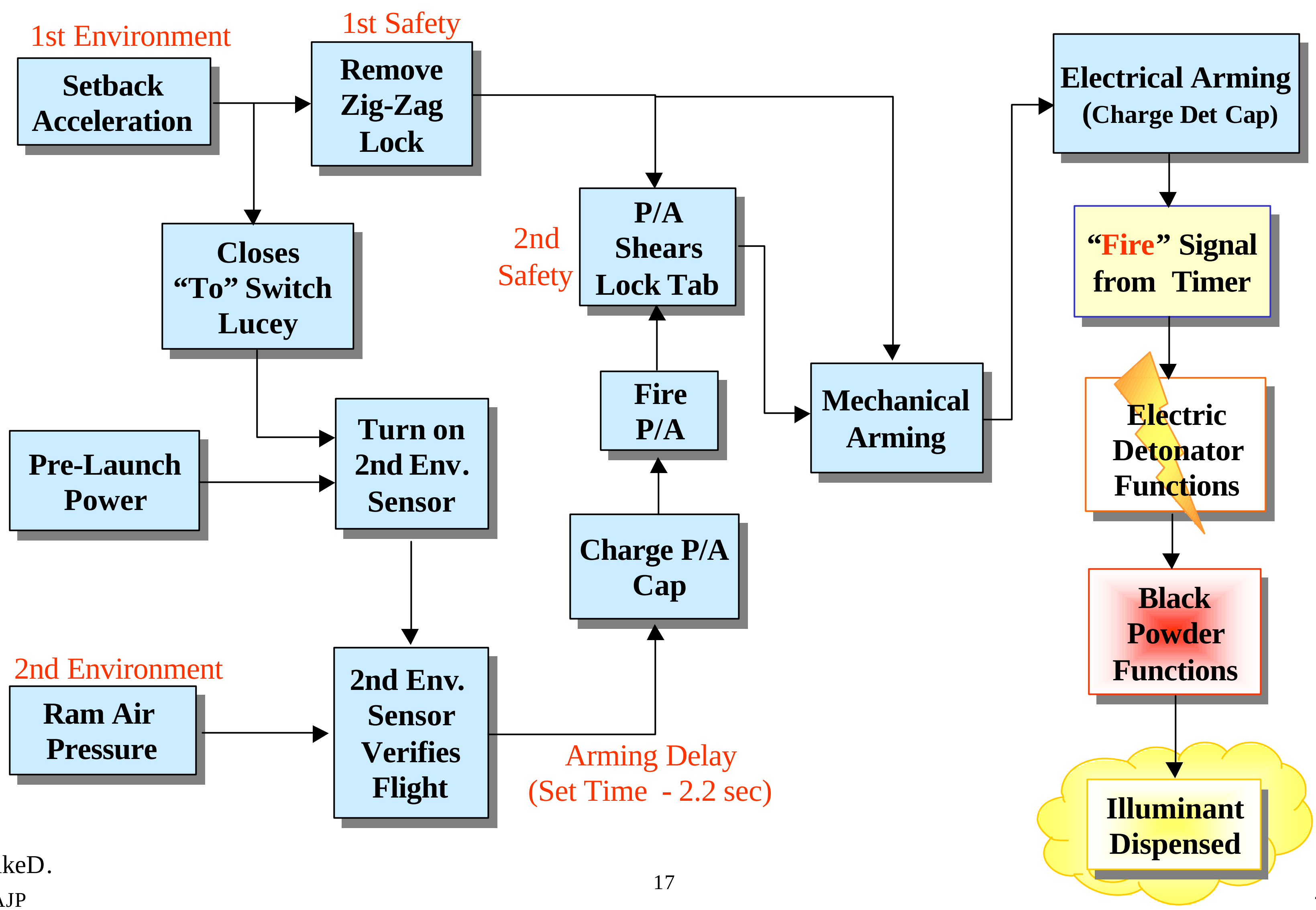


XM784/ XM785 ET Fuze for Mortars
Safe and Arm Device

- **Design approaches:**
  - **Command arm w/ piston actuator (stored energy)**
  - **Evaluated air powered arming**
    - **removing a lock then spring driven in-line**
    - **directly arming the fuze**
- **Zig-zag setback lock with switch closure**
- **Designed both barrier and rotor approaches**
- **Develop PRO-E layout to generate SLA hardware**

Safety Logic Diagram - ET Fuze for Mortars

(Version B)

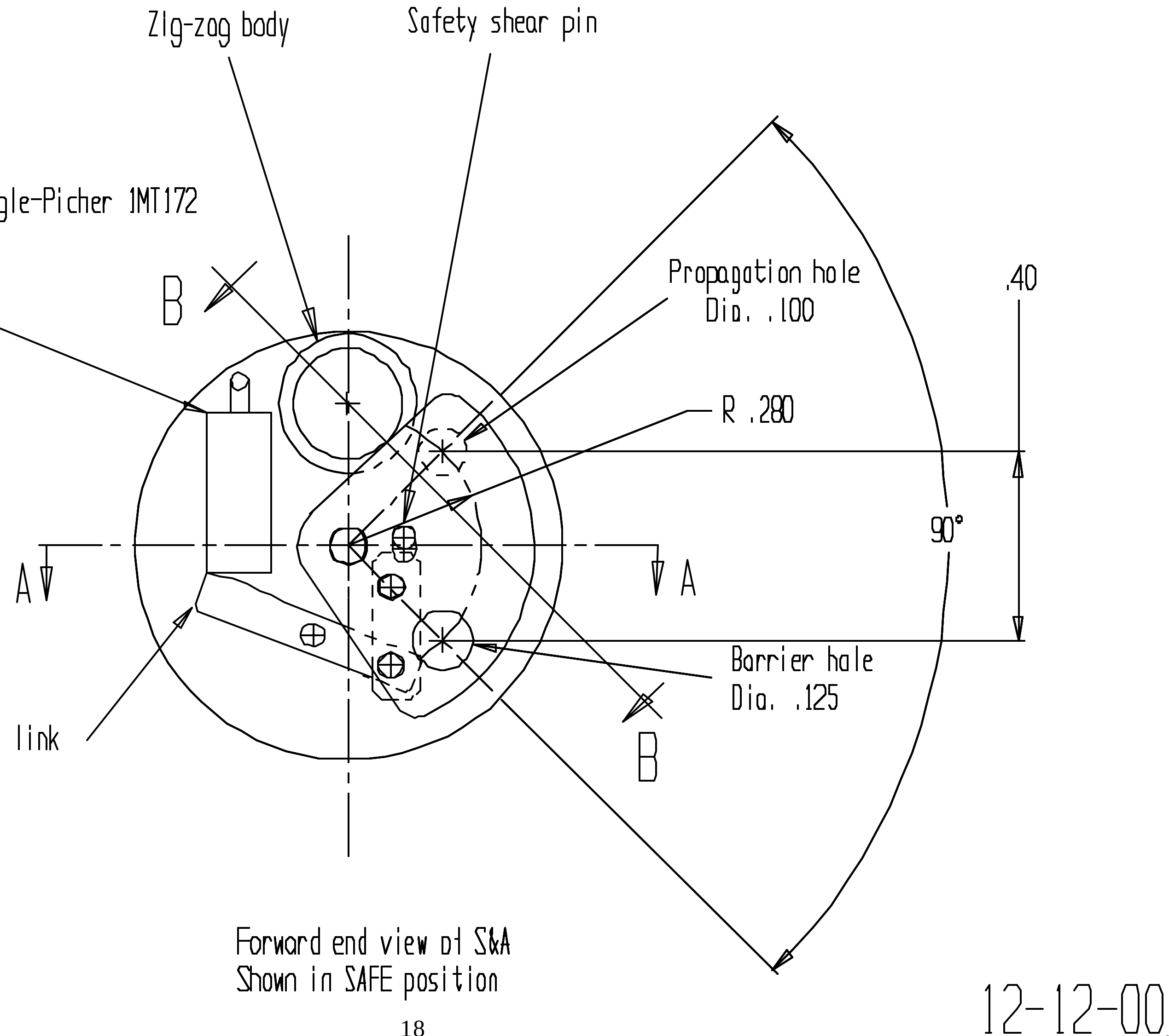


Ward/MikeD.
DWW/AJP

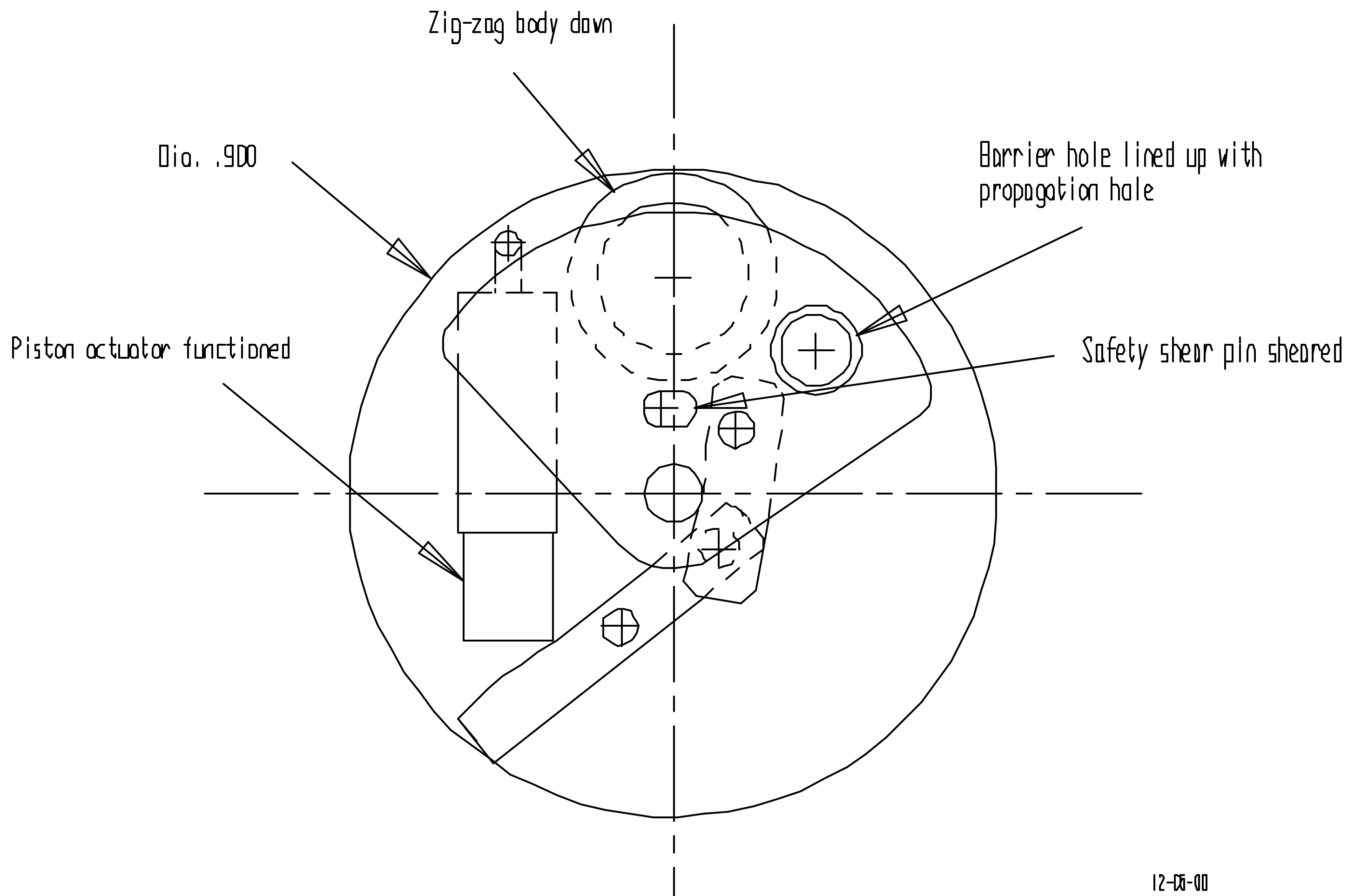
4/18/01

XM784/ XM785 ET Fuze for Mortars

S&A (safe position)



XM784/ XM785 ET Fuze for Mortars
S&A (armed position)



S&A in ARMED position

XM784/ XM785 ET Fuze for Mortars

S&A (zig-zag)

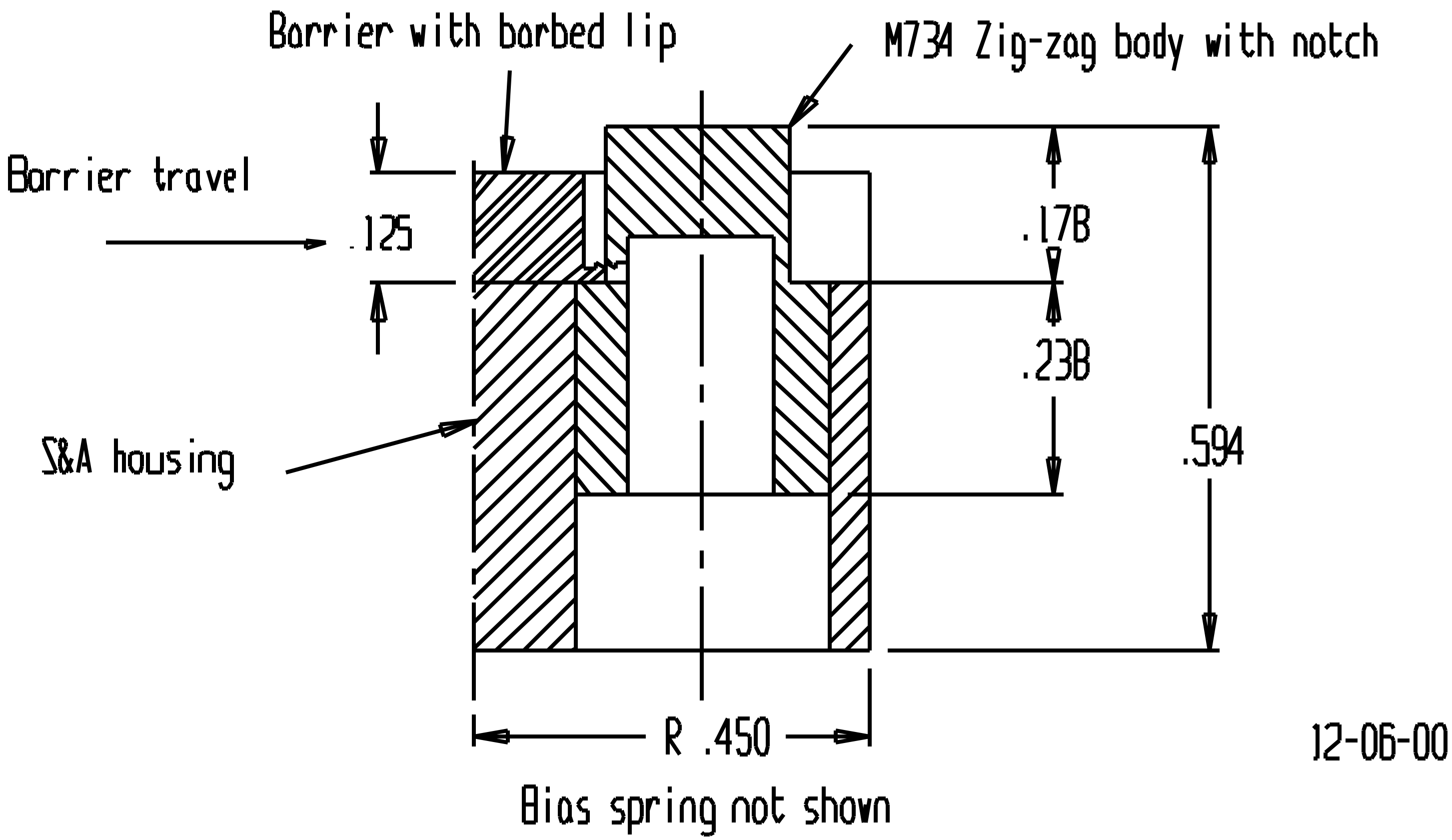


Fig. 3 Half-Section of Fail-Safe Latching Barrier for Angular, Out-of-Plane S&A Layout

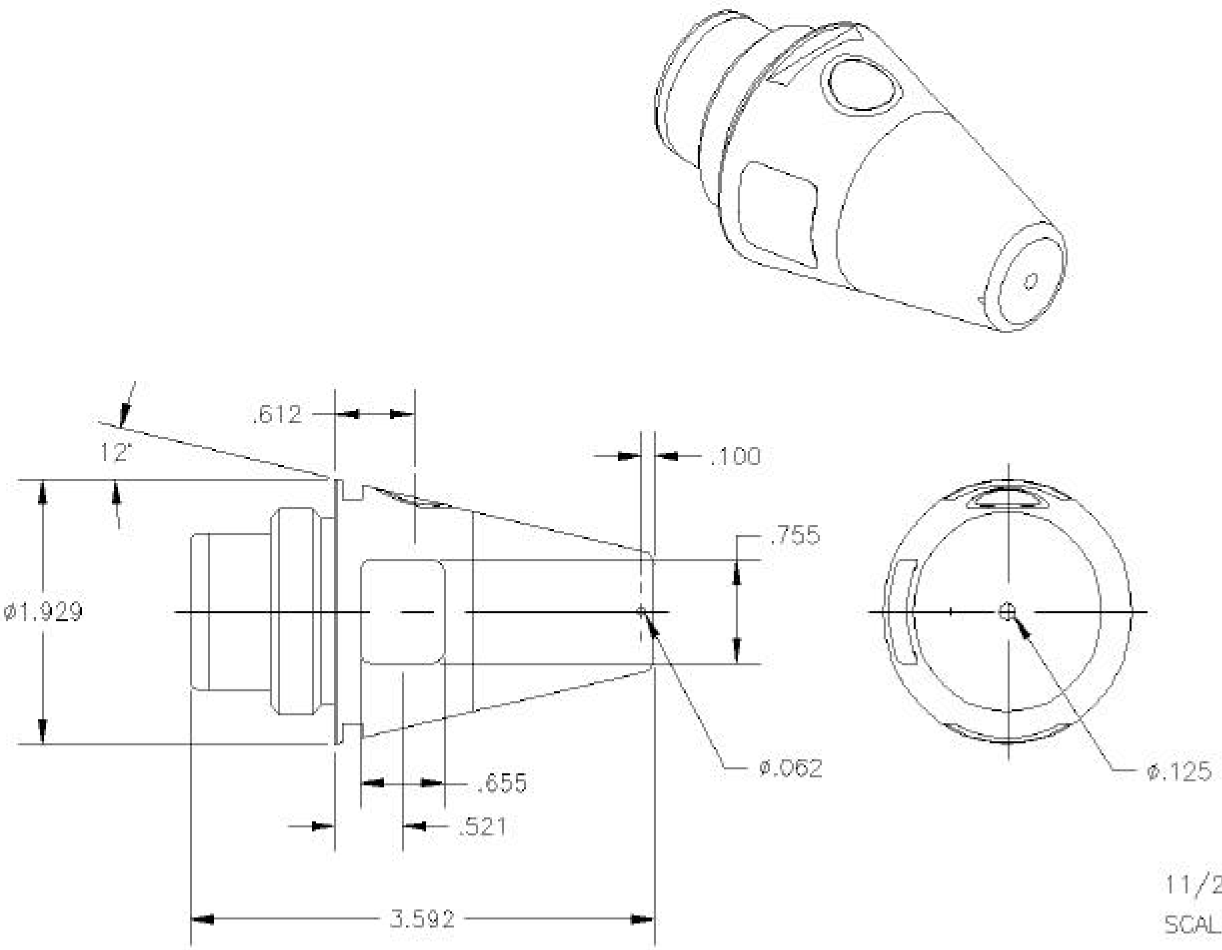
XM784/ XM785 ET Fuze for Mortars
Explosive Train

- **Utilized explosive experts**
  - **Generated a matrix of possible candidates**
- **Identified a possible on-shore source for black powder**
  - **M10 to be considered as a replacement**
- **Concepts to initiate black powder:**
  - **Electric detonator or primer initiates powder directly**
  - **Electric match initiates intermediate chg (environmental stability a concern)**
- **Conduct explosive tests with candidate initiators**

XM784/ XM785 ET Fuze for Mortars
Packaging and Hand Setting

- **Generated Packaging Layouts**
  - **Vertical and Horizontal Circuit Boards**
  - **Utilizing flex circuit concept**
- **Handset scheme similar to M762**
- **Used NDI / custom LCD's (M762 Based)**
- **Developed a PRO-E model**
  - **Handset concept (SLA prototype)**

XM784/ XM785 ET Fuze for Mortars
Packaging Model



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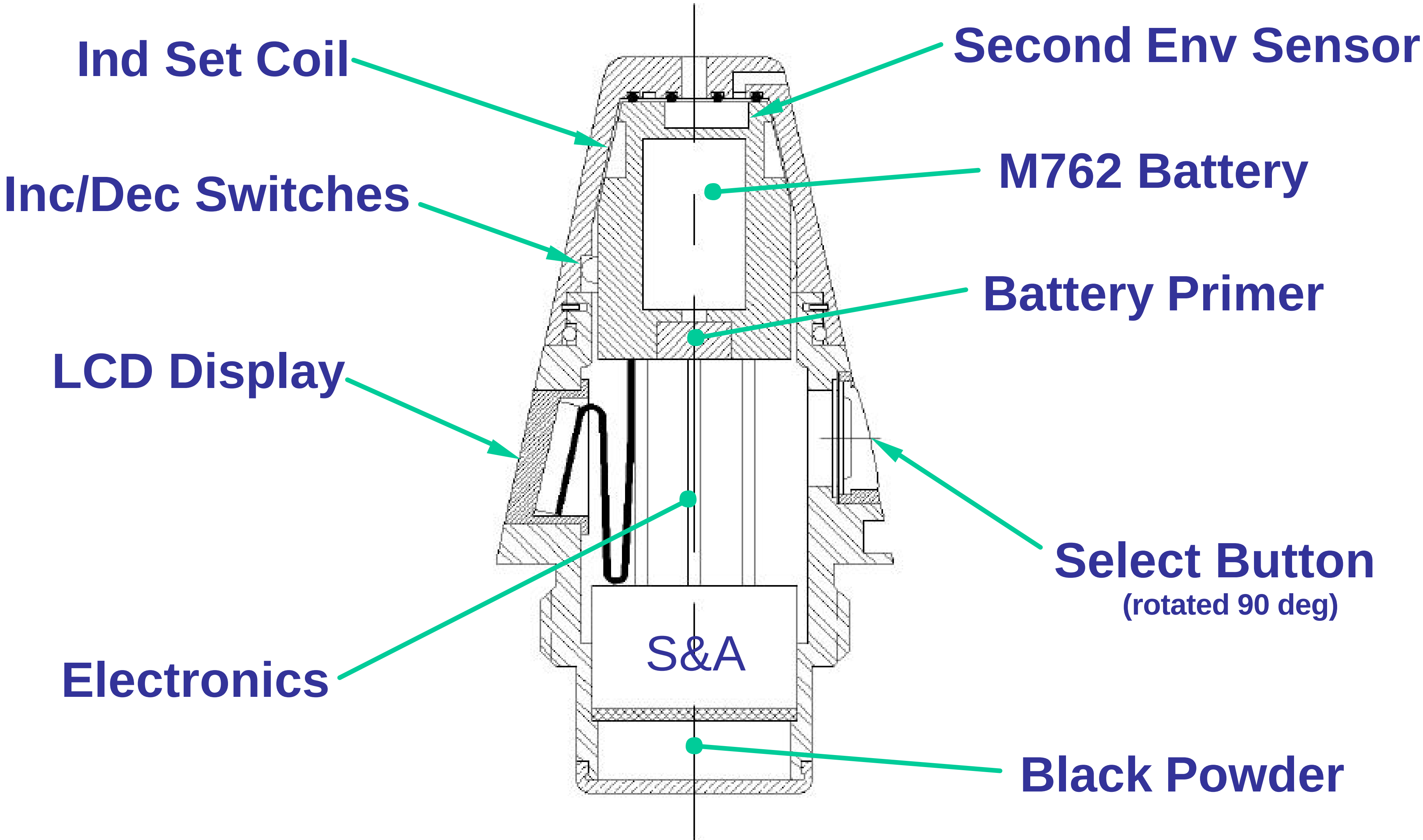
XM784/ XM785 ET Fuze for Mortars
Packaging Concept



XM784/ XM785 ET Fuze for Mortars

Summary

- Planning Contract Award In June 2001
  - Design & Development
  - Test & Type Classify
  - First Article & Materiel Release
- Developed Initial In-House Design Concept
- Will Use Best (Cost Effective) Design Approach
  - Proposed Contractor Solution
  - Government Design
- Gov’t Electronics Design Approach Follows….

New Developments in Sensitivity Testing

Dr. Barry T. Neyer
Director of Research and Development
PerkinElmer Optoelectronics
PO Box 529
Miamisburg, OH 45343

NDIA Fuze Conference
April 16-18, 2001

Lessons Learned from Studying Birds and Bunnies Applied to Building a Better Bomb

Dr. Barry T. Neyer
Director of Research and Development
PerkinElmer Optoelectronics
PO Box 529
Miamisburg, OH 45343

NDIA Fuze Conference
April 16-18, 2001

Talk Outline

- Review of sensitivity testing
- Old and optimal sensitivity test designs
- Non sequential designs
- Simulation Results
- Practical Uses of New Techniques

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How Do You Test Explosive Sensitivity?

- Assume each explosive has a unique threshold:
  - » Hit it harder: explosion; hit it softer: no explosion.
- Can't measure detonator initiation threshold, only determine if a stress is smaller or larger than given a detonator's threshold.
- Can only test each sample once:
  - » Exploded samples gone; unexploded samples changed.

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A True Sensitivity Test has These Characteristics:

- Can test each sample only once.
- There is a unique threshold for each sample.
  - Larger stress always leads to response.
  - Smaller stress always leads to no response.
- Function of the thresholds follow known (normal distribution).
- *No duds.*

Sensitivity Test & Analysis Used in a Wide Variety of Fields.

- Explosive sensitivity
- Strength of materials
- Toxicity
- Oxygen deprivation
- Pharmaceutical testing
- Radiation tolerance

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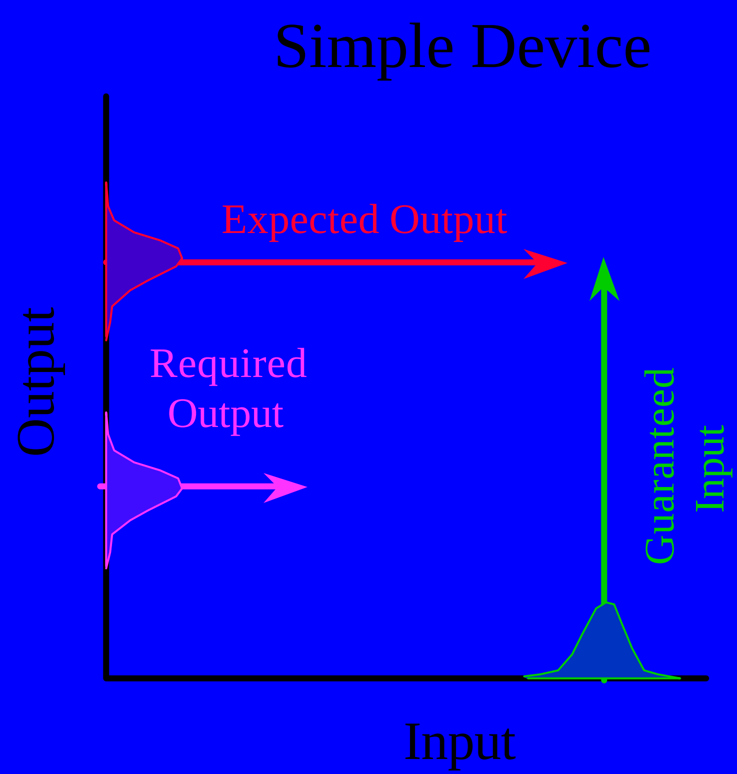
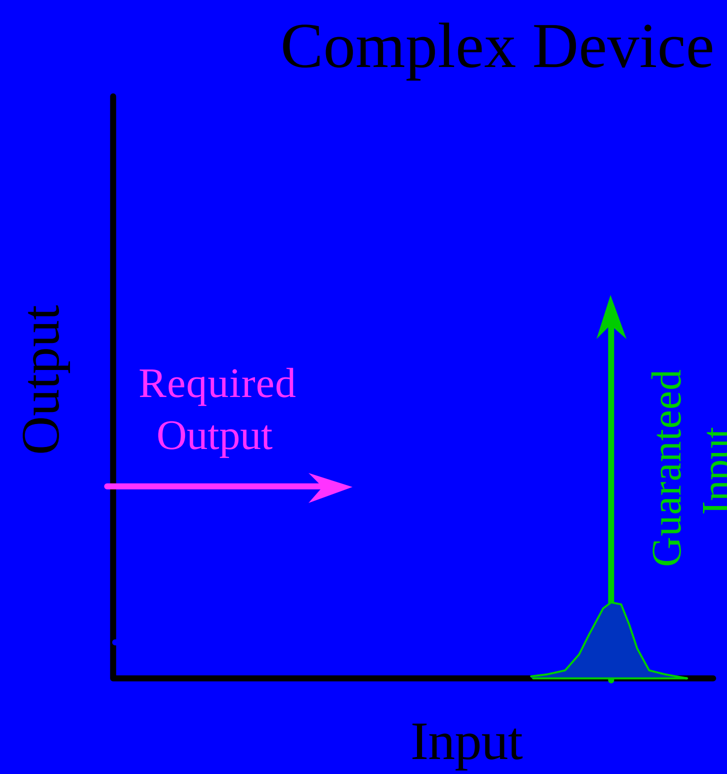
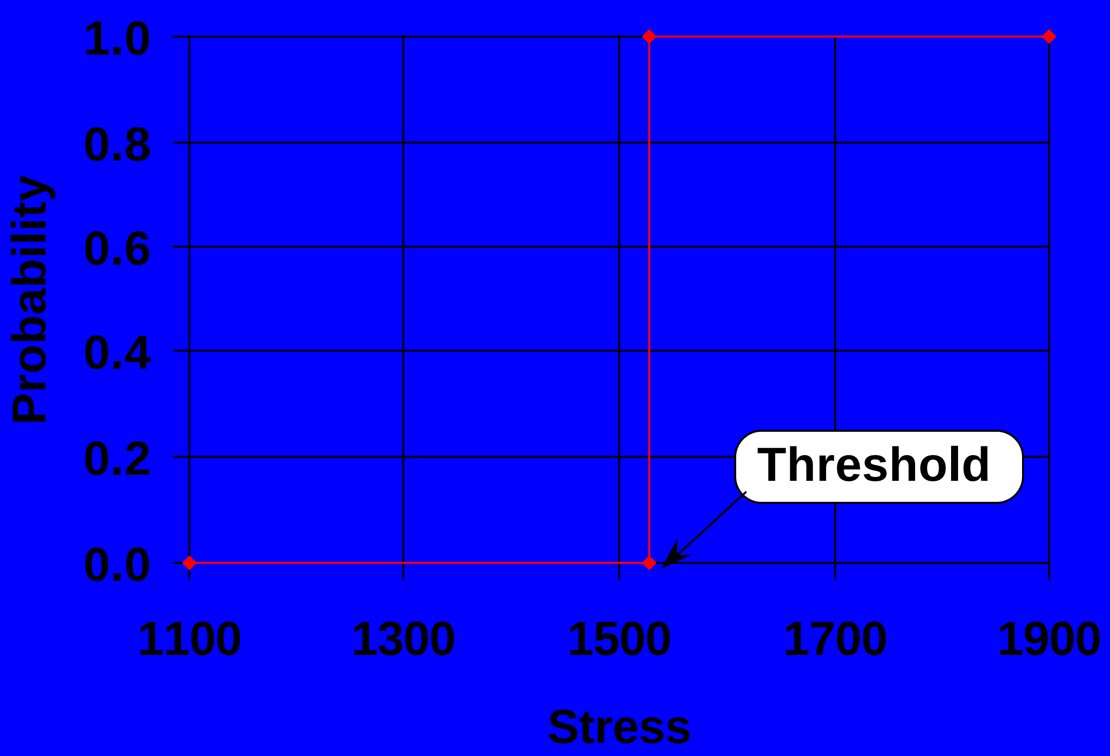
It is Easy to Determine If Simple Devices Meet Interface Requirement.

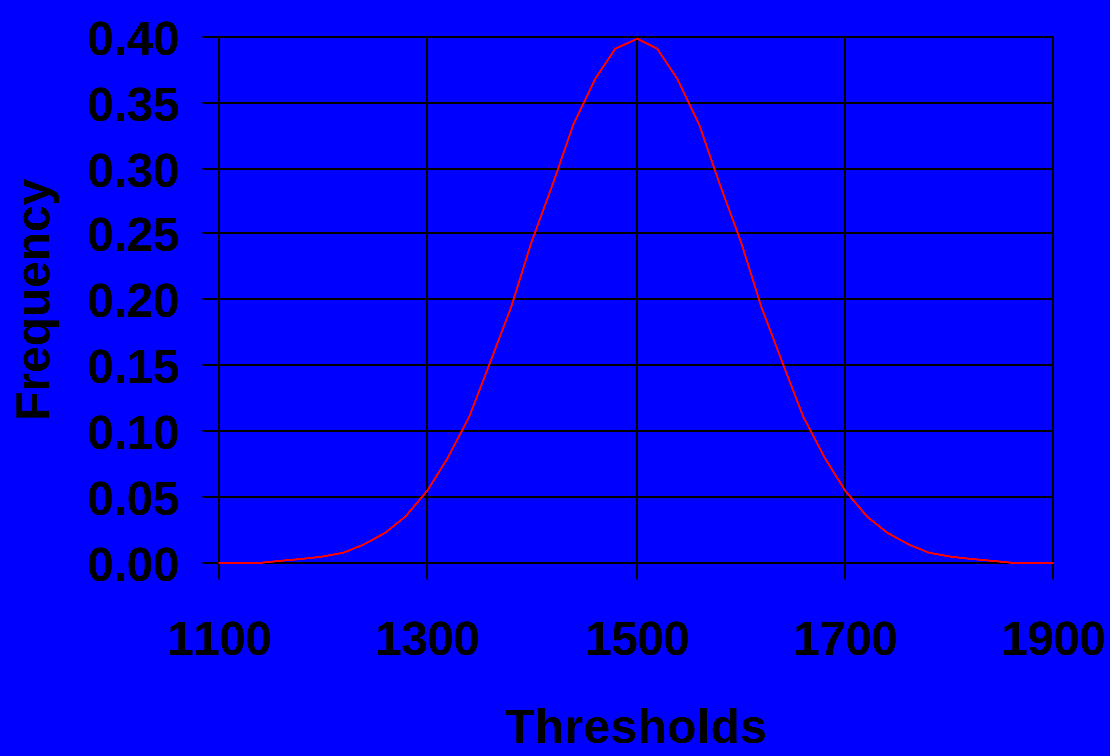




Components Respond If the Stress is Larger Than the Threshold.



If Component Thresholds Follow the Normal Distribution:



The Probability that a Component Chosen at Random Will Respond is:

What is an Optimal Design?

- All tests not created equal.
- If all responses or failures, you learn nothing.
- Amount of knowledge gained for each test is a function of test level.
- Need to pick test levels to maximize knowledge.
- If you learn the maximum amount statistically possible, it is an optimal design.

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Other Tests Were Designed Many Years Ago.

- Probit Test (1900). Fixed design requires many samples.
- Bruceton (1940). Designed to allow easy computation of estimates of the parameters.
- Delayed Robbins-Monro (1950). Designed to home in on mean of the population.
- Langlie (1960). Designed to give better estimates of sigma when initial knowledge was uncertain.

The D-Optimal Test Uses a Three Step Procedure.

- Use a modified binary search to find the mean.
  - » Get 1 success and 1 failure as quickly as possible.
  - » Close in on mean.
  - » Check convergence if needed.
- Use guess for Sigma and test for maximum information.
  - » Decrease guess for Sigma until overlap.
- Update knowledge of Mu and Sigma and continue to test for maximum information.

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Most Often Explosive Components are Tested Sequentially

- Test equipment is expensive.
- Can only test one component at a time.
- Easy to vary stimulus level.
- Know the results instantly.

- Use knowledge of all N results to pick test level N+1.

Explosive Transfer Studies are More Complicated

- Vary the donor or acceptor to establish the transfer reliable.
  - VariDrive or VariComp
- Must build components with different explosive density, length, etc.
- Large time delay between knowledge of requirement and delivered hardware.
- Sequential test designs not currently used.

Similar Test Complications Exist in Biological Experiments

- Instead of supplying the critical **energy** that is sufficient to cause the **device** to **explode**, biologists supply the critical **dose** that is sufficient to cause the **animal** to **die**.
- It often takes days or weeks for the effects of the dose to kill the animal.
- Sequential test designs not currently used.

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Work with Groups Studying Test Designs for Birds and Rabbits Led to New Test Design

- The critical factor is the ability to chose several test levels at a time:
  - Time to determine effects of biological experiments
  - Time to manufacture explosive components
- Design a test that maintains advantages of present D-Optimal design, but allows choosing multiple test levels at one time.

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Modification to D-Optimal Method Allows for Choosing Multiple Test Levels

- Use same three population estimates, MuMin, MuMax, SigmaGuess
- First time(s) through spread out test levels uniformly
- When close to SigmaGuess spread out between 2 D-Optimal points
- When levels overlap, place levels at 2 D-Optimal points

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Simulation Shows that Modified D-Optimal Method is Very Efficient

- Perform simulation with realistic knowledge of Mu and Sigma
  - Know Sigma within a factor of 2
  - Know Mu within 2 standard deviations
- Look at Mu, Sigma, and All-Fire estimates
- Variance of estimates indicates efficiency
  - Variance has 1/N dependency

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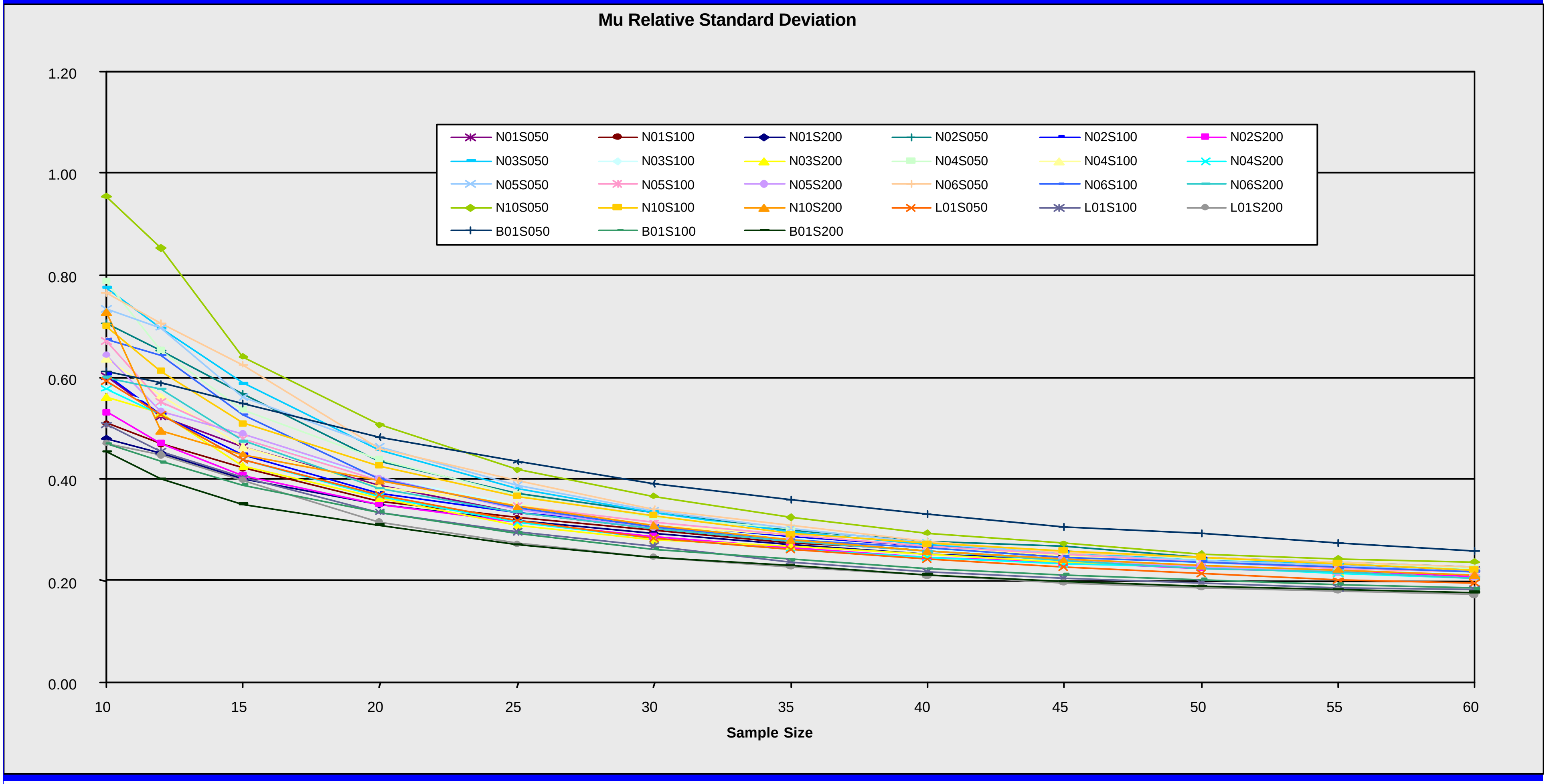
Simulations of 1000 Repetitions Were Performed for 27 Cases



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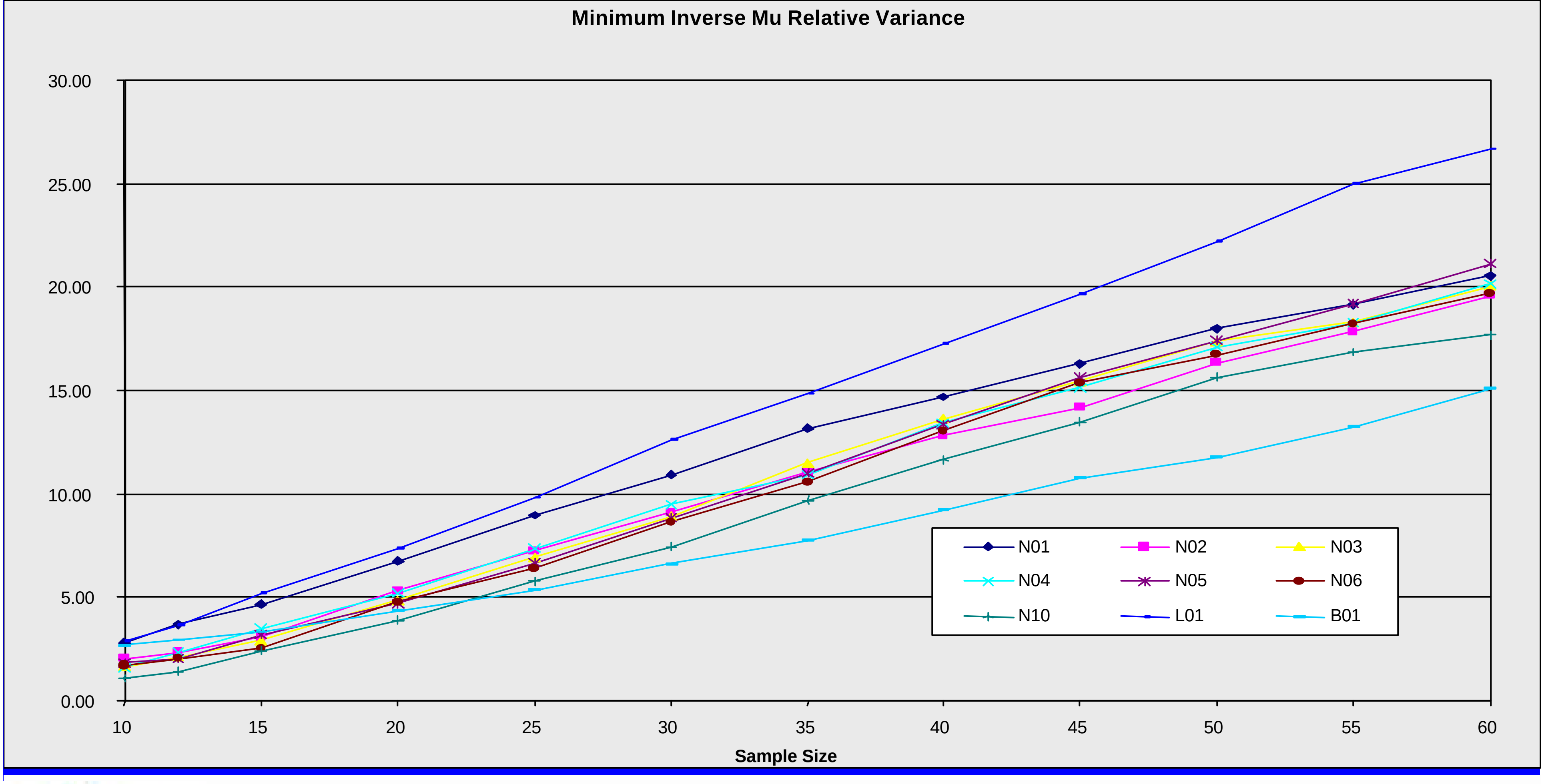
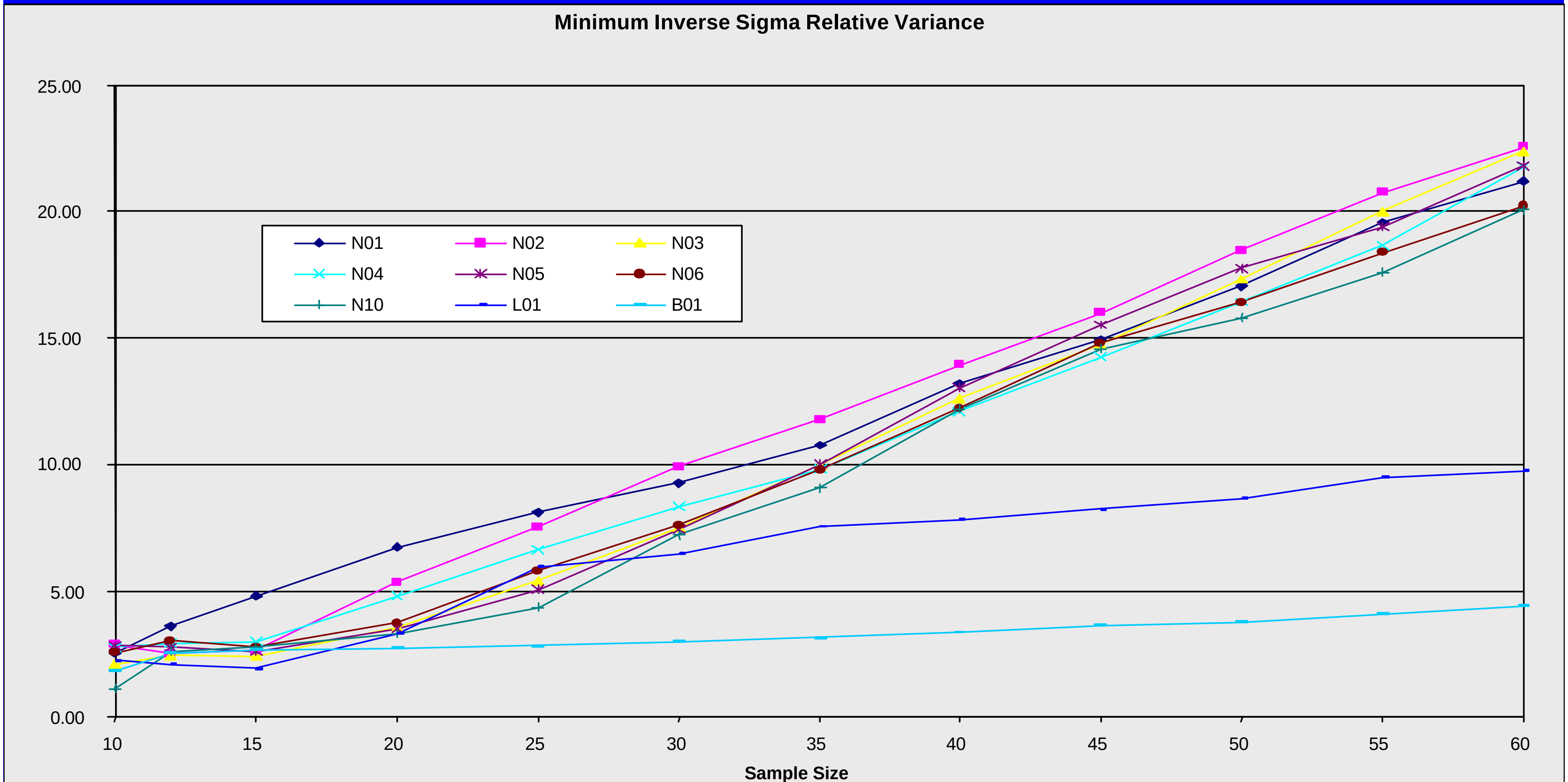
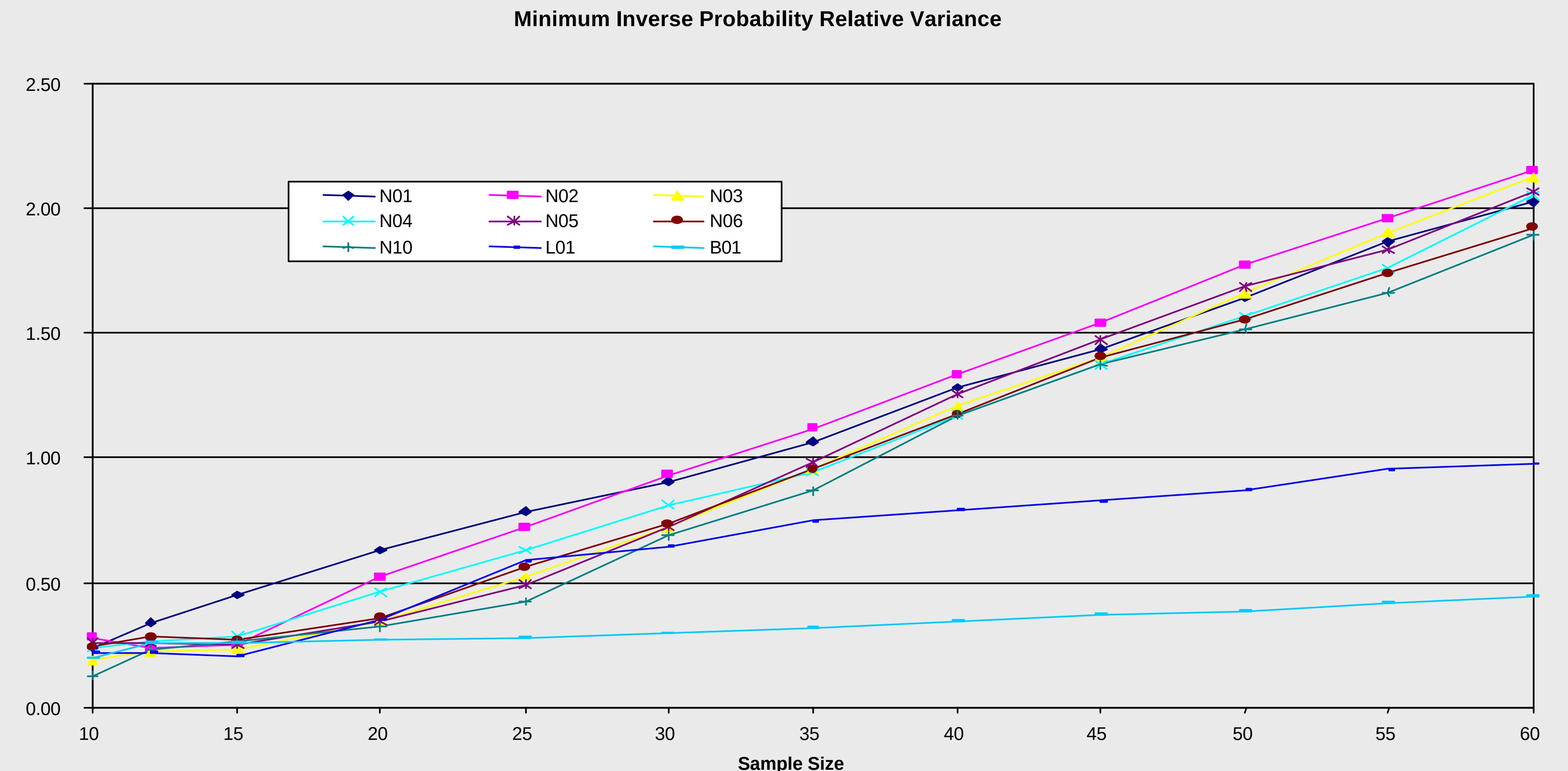
Little Change in Mu Efficiency when Picking Up to 10 Tests Simultaneously



Little Change in Sigma Efficiency when Picking Up to 10 Tests Simultaneously



Little Change in All-Fire Efficiency when Picking Up to 10 Tests Simultaneously



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The Decrease in Efficiency Can Be Estimated

- As long as there are at least 4 steps (stages)
  - Simultaneously testing ***S*** units at a time gives similar results to testing ***S-1*** less units. (Testing 25 units picking 5 test levels at a time gives similar results to testing 21 one at a time.)
- Mu, Sigma, and All-Fire levels are all better when picking test levels 1 or a few at a time.
  - More simulation with 10,000 repetitions needed to fine tune result

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The Modified D-Optimal Test Method Can Be Used In Many Applications

- Whenever it takes time to produce the test levels
  - VariDrive and VariComp experiments
- Whenever the test results are not known for some time
  - Maximum no damage current tests

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A MODULAR APPROACH TO ELECTRONIC FUZE DEVELOPMENT

MIKE TUCKER

FUCHS ELECTRONICS

PRESENTATION CONTENTS

- Company Background
- International Fuzing Trends
- Customized Fuze Features
- Risk Areas in Artillery Fuze Development
- Development Approach
- Fuze Components
  - Customized Features
- Derived Range of Fuzes
- Future Possibilities
- Summary
- Conclusion

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FUCHS ELECTRONICS - BACKGROUND

- Privately owned South African Company
- Designs and Manufactures Electronic Fuzes for Tube-Launched Ammunition
  - Artillery Fuzes
  - Rocket fuzes
  - Naval Fuzes
  - Mortar Fuzes
  - Fuze Setting Systems
- Staff of Approx. 280
- Supplies Internationally to Ammunition Suppliers and end-users
- Almost 100% of Production is Exported


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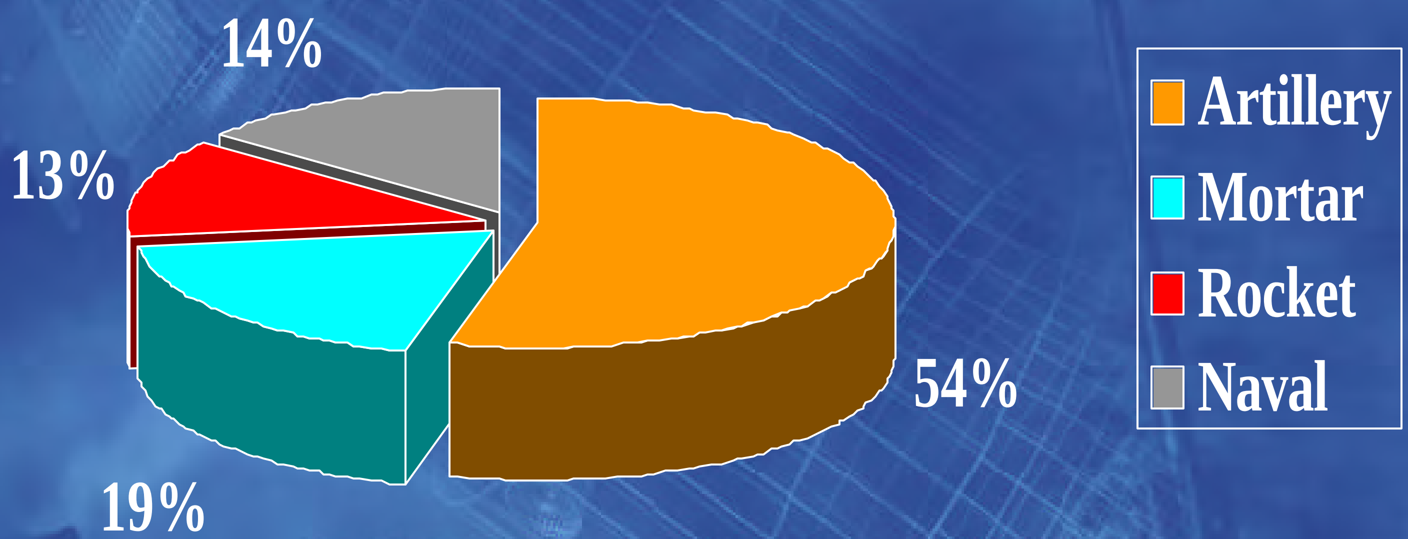
FUZE PRODUCTION PERCENTAGES
BY PRODUCT TYPE *



* Based on sales of past 20 Years

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International Artillery Fuzing Trends

- Customer Requirements:
  - Short Timescales – Typically 4 to 6 months to Production
  - Reduced Production Volumes
  - Customized Features
  - Proven Safety, Reliability and Qualification Status
  - Very High Probability of Project Success

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Customized Fuze Features

- Safety Times
- Burst Heights
- PD Backup feature and its Arming time
- Multi Role Usage e.g. Proximity, Time, PD, PD Delay
  - With or Without Delay Function
  - Post Impact Delay Time
- Function Switch
- Inductive Settable Features
- On-Board Displays of e.g. Time Set

- Delivery Timescales are always shorter than needed for a full development cycle !

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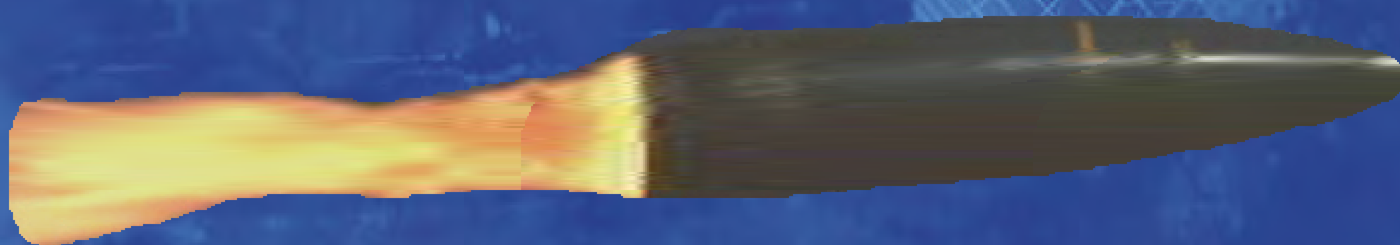
Risk Areas in Artillery Fuze Development

- Component breakage due to launch stresses at Highest Charges
- Survival of in-flight temperatures and pressures
- Trajectory Bursts due to:
  - Noise effects
  - Vibration
  - Ammunition instability
- Compatibility with Rocket Assisted or Base bleed Ammunition
- High Cost of Dynamic Proofing
- Lead times of Electronic components



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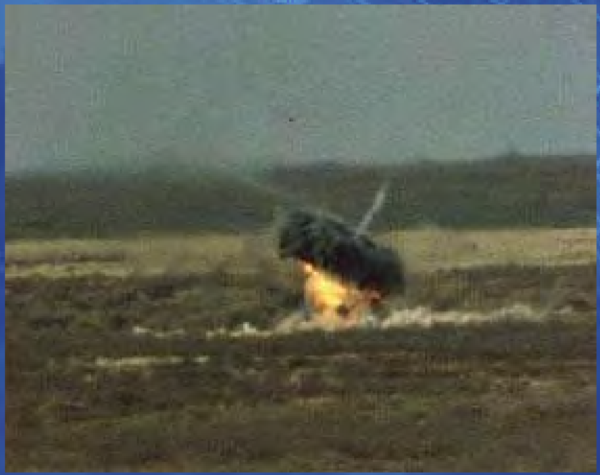
Development Approach

- To satisfy the requirements, the following approach has been adopted successfully:
  - Use Integrated Development Teams within the company:
    - Electronics Engineers
    - Mechanical Engineers
    - Pre-Production Representatives
    - Instrumentation Development Enginers
    - Quality Control Engineers



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Development Approach - II

- Use of proven “Building Blocks”
- In-house Prototype Manufacturing Department
- Regular Dynamic Proofing
  - Use of In-Flight Telemetry
  - Easy access to well instrumented Proof Ranges
- Development of Dedicated Test Instrumentation

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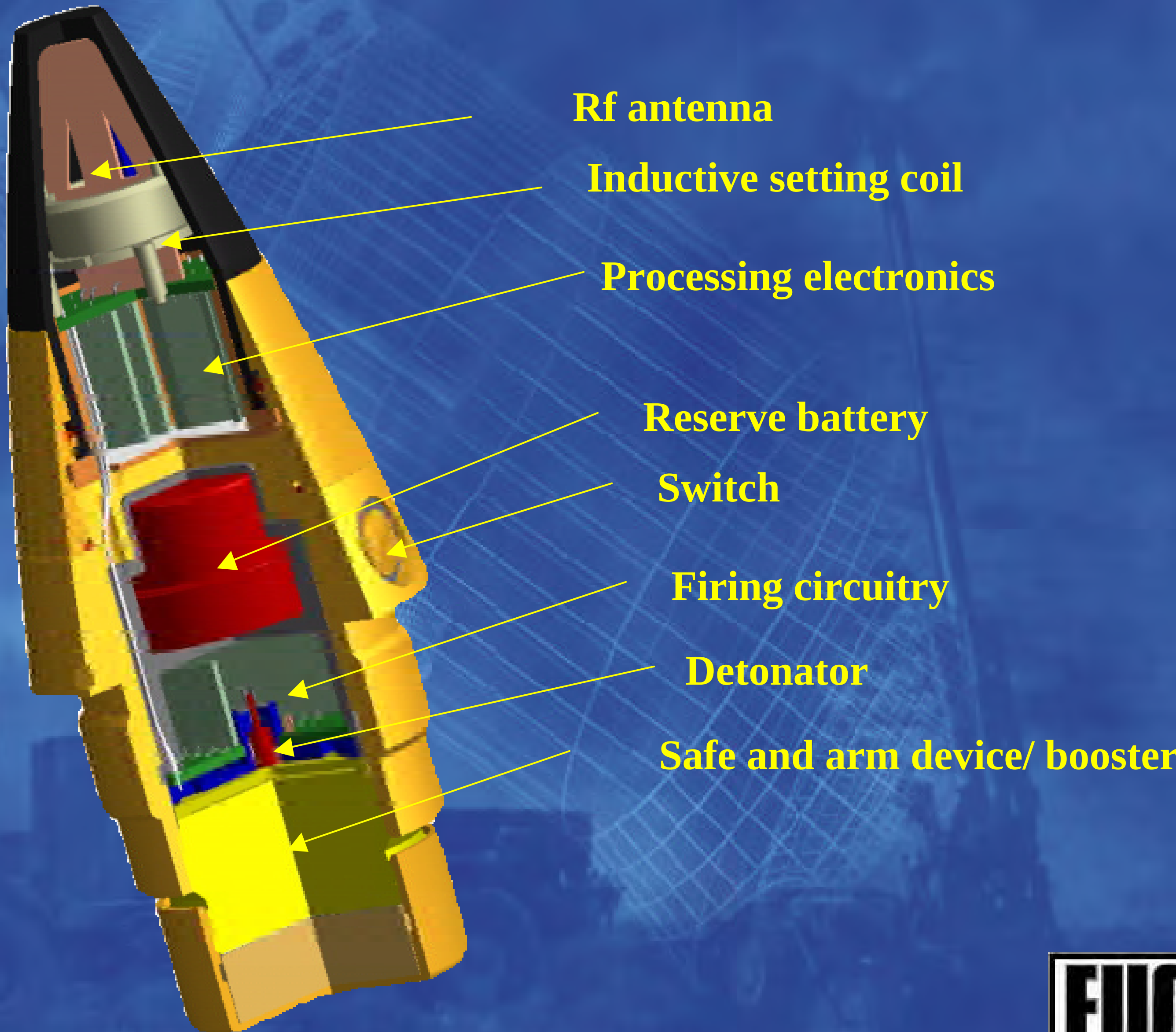
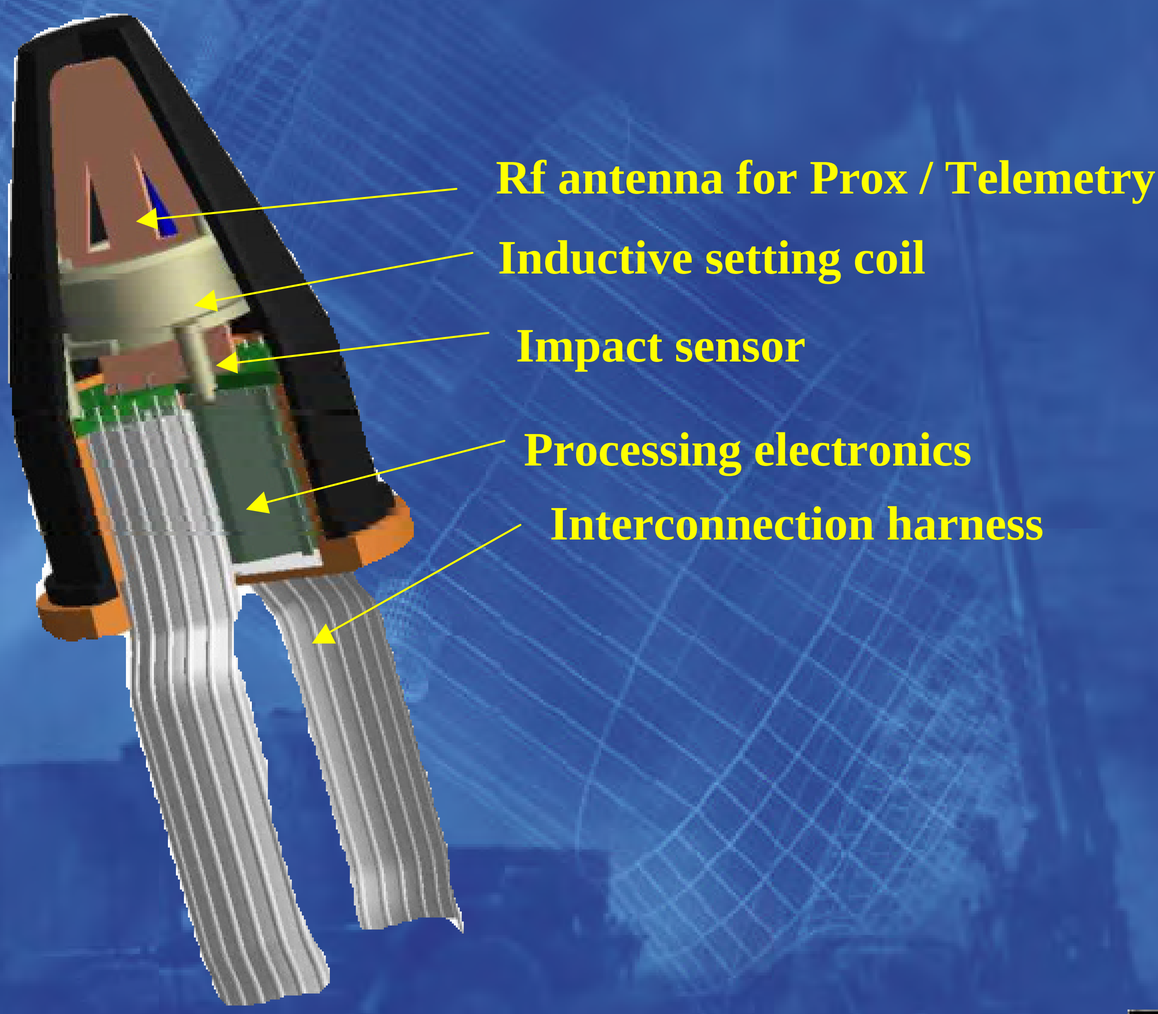
Typical electronic fuze components



Electronic head assembly



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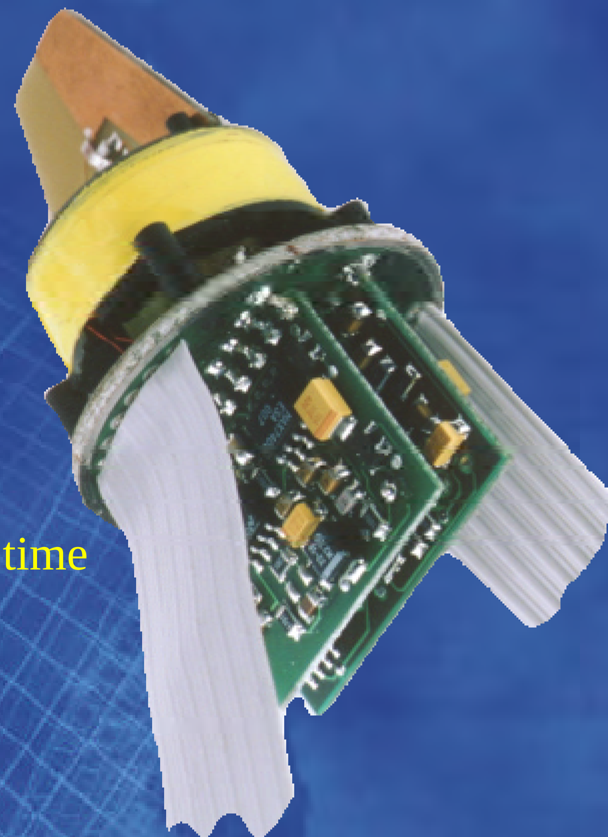
Electronic Head Assembly

- STANDARD FEATURES:
  - Microprocessor Controlled
    - Software programmed during final assembly
  - Inductively Settable or Factory Set Only
  - DATA stored in EEProm
    - Re-Writeable via Inductive coil interface
    - Mission Settings, e.g. Proximity with 6.5 sec Safety time



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Electronic Head Assembly

- CUSTOM FEATURES
  - Proximity / Time / PD Functions
    - Safety Time for PD Backup
    - Proximity Enable / Safety Time
    - Proximity Algorithm
    - Burst Heights
  - Switch Setting
  - Production / Engineering Settings
    - RF Transmission Characteristics
    - Signal Processor Characteristics
    - Telemetry Features

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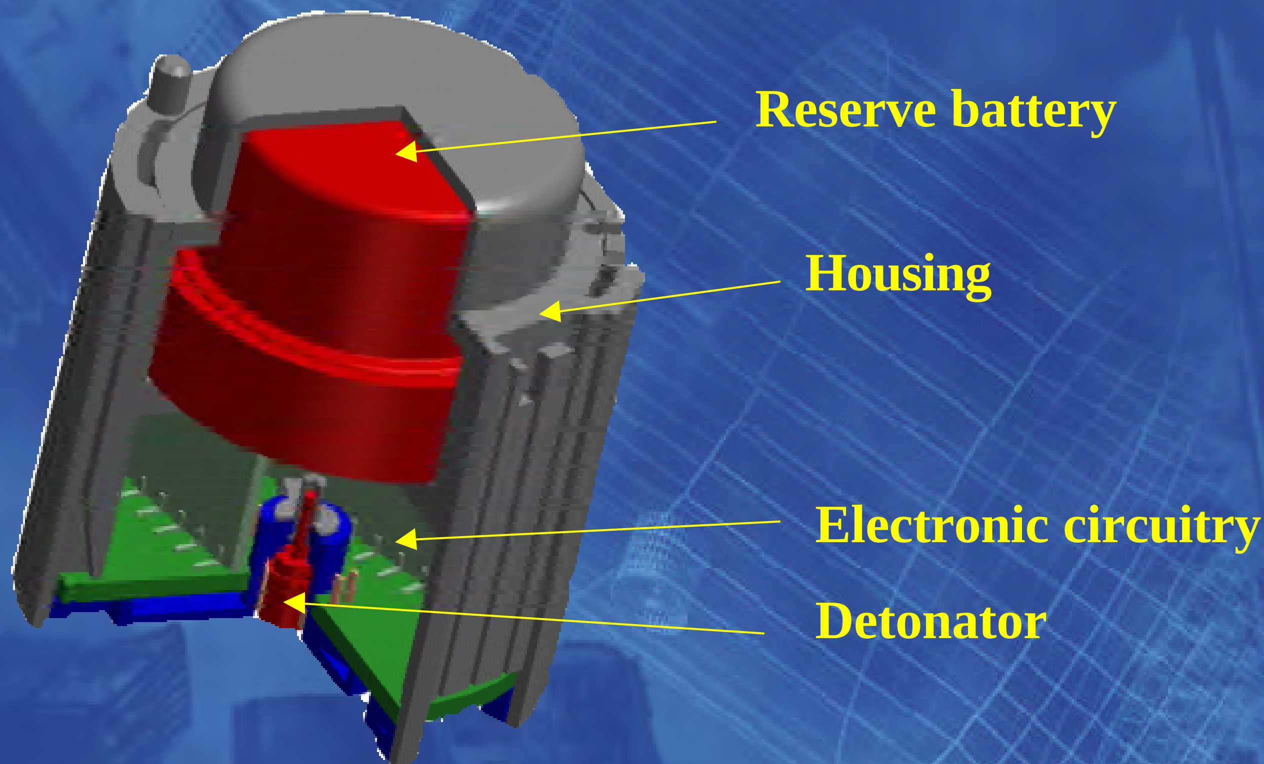
Lower module assembly



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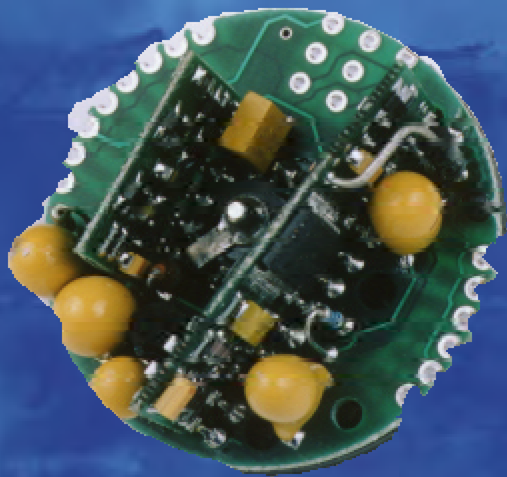
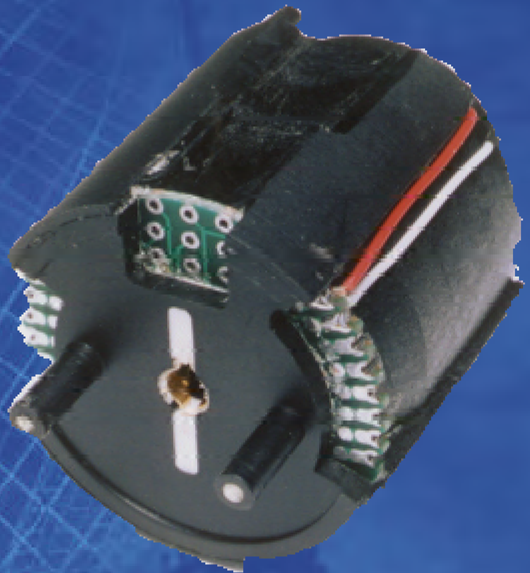
Lower Module Assembly

- FEATURES:
  - Fire circuitry
  - Power supply circuitry
  - Detonator interface
  - Interface to switches or displays
- CUSTOM FEATURES
  - Fire circuit safety times
  - Post impact delay time





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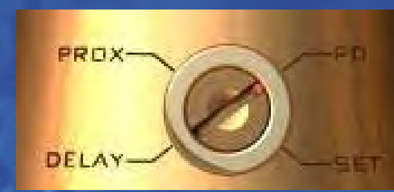
General construction

Display



Mode switch

General Construction

- FEATURES:
  - Houses all sub-assemblies
- CUSTOM FEATURES
  - Switches for MOFA or PROX/PD
  - Buttons for time fuze setting
  - Display for time fuze setting
  - Safe and arm device
    - 40m or 200m Options

SAFE AND ARM DEVICES

DISPLAY

FUCHS ELECTRONICS

Derived Range of Artillery Fuzes

ARTILLERY PROXIMITY,

ELECTRONIC PD / DELAY

AND MOFA FUZES

ARTILLERY TIME FUZES

FUZE SETTER

FUCHS
ELECTRONICS

Future Possibilities

- Further Enhance Flexibility by:

- Mid – Life Software Upgrade to Fuzing Systems
  - Depot Modification of Microprocessor code via Inductive Setting Coil
  - (Currently done by hard wiring at final production stage)

- Examples:
  - Convert Proximity Fuzes to Multi-Role Fuzes
  - Upgrade ECCM features as a software retrofit
  - Improve reliability by use of improved signal processing

FUCHS ELECTRONICS

Summary

- Benefits of a modular development approach:
  - Significantly reduced number of Dynamic Firings
  - Reduced Development Time
  - Reduced Technical Risk
  - Increased Manufacturing Flexibility
    - Different Fuzes can be produced with the same material
  - Reduced Life cycle cost
    - Software only Mid-life upgrades
  - Re-work or Re-use of fuzes without physical disassembly

FUCHS ELECTRONICS

CONCLUSION

A modular approach to electronic fuze development assists in reducing 'time to market' and development costs as well as reducing risks involved in adopting untested hardware

FUCHS ELECTRONICS
Dependable Fuze Technology

FUCHS ELECTRONICS

Storage Reliability of Reserve Batteries

Jeff Swank and Allan Goldberg
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Adelphi, MD
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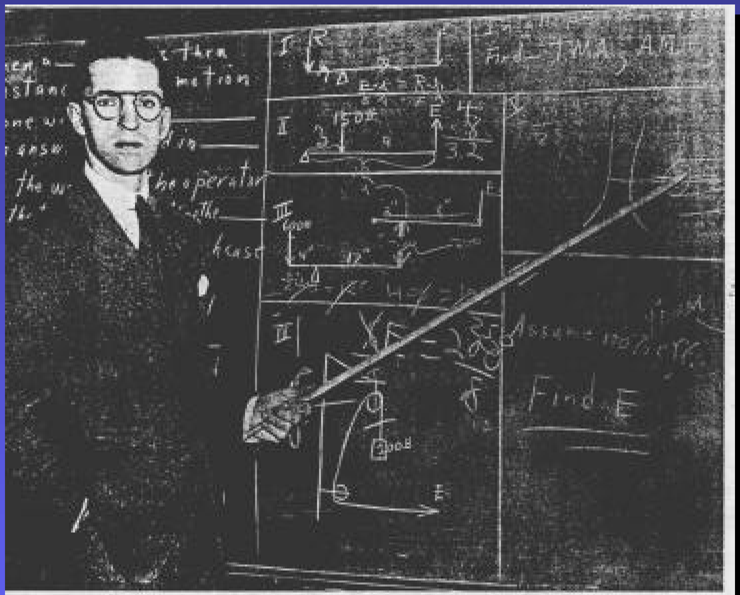
At Issue

- Items developed for munitions have a 20-year shelf life requirement over a wide temperature range
- Developers need to “prove” storage reliability
  - Actual documentation preferred
- Science can be difficult, time-consuming, and costly



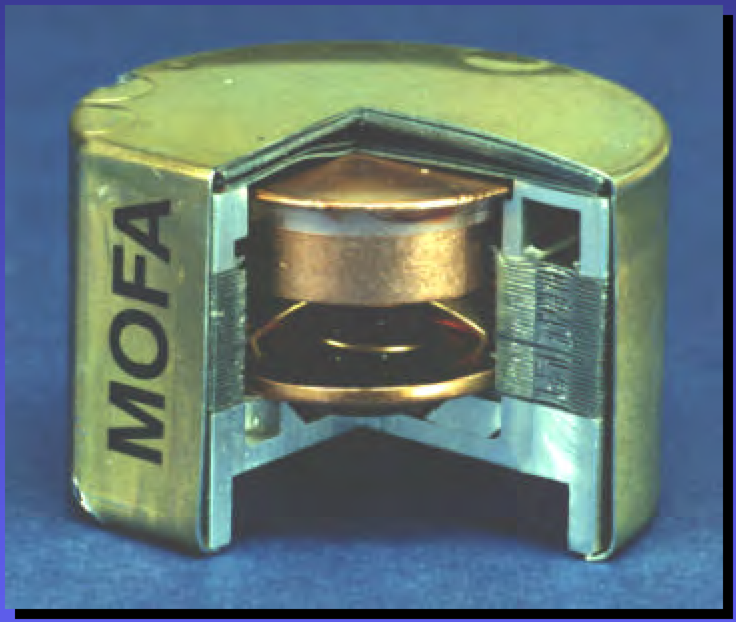
Never mind how we're doing it.

Reservoir Evolution

- Army and Navy used $Pb/HBF_4/PbO_2$ reserve batteries with glass reservoirs
- Over time it was discovered that batteries became more sensitive to activation when dropped
- Glass was being attacked by the aqueous electrolyte
- Drove change to copper dash-pot design

Reservoir Evolution

PS112 Ampoule



ARL MOFA battery (sectioned)

A Common Approach

- Put samples in high-temperature storage
  - Rule-of-Thumb: reaction rates double with every 10°C increase
    - 1 year at 65°C = 16 years at 25°C
- Periodically pull samples and test battery performance
- Analytical work kept to a minimum

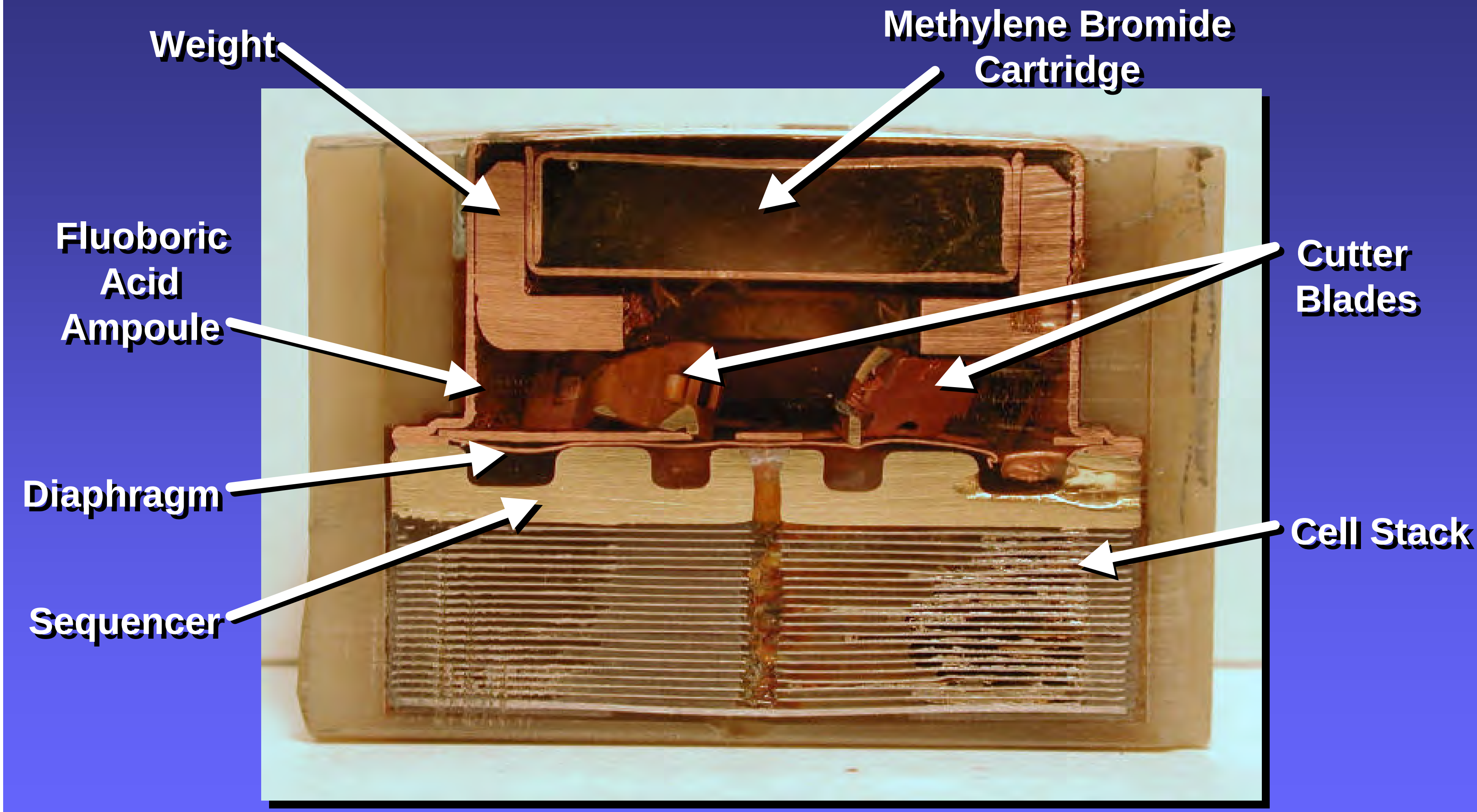
Potential Drawbacks

- Previous slide predicts aging at *25°C*
- How to accelerate aging at high temp conditions?
  - Increase beyond 74°C (165°F), but risk introducing new effects or reactions
  - Increase study time
- Might miss subtle changes that indicate trouble
- Might mask problem altogether

PS115: A Case Study

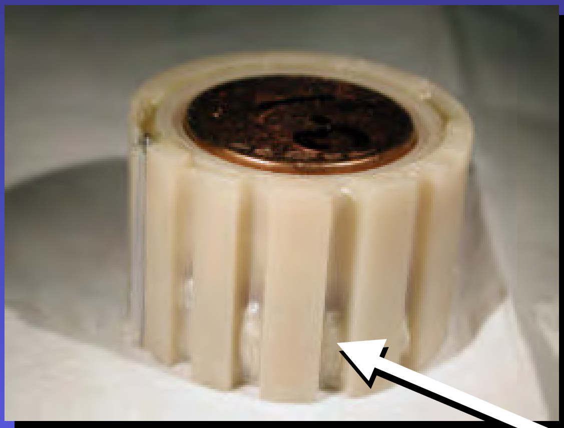
- Dual-fluid, copper reservoir design
  - Fluoboric acid electrolyte
  - Methylene bromide (non-conductive, more dense)
  - Sequenced release of fluids
- Developed in 1964, used in M732 fuze starting in 1978
- Initial studies of reservoir/electrolyte materials indicated they were compatible
- Accelerated aging at 71°C (160°F) indicated no problem

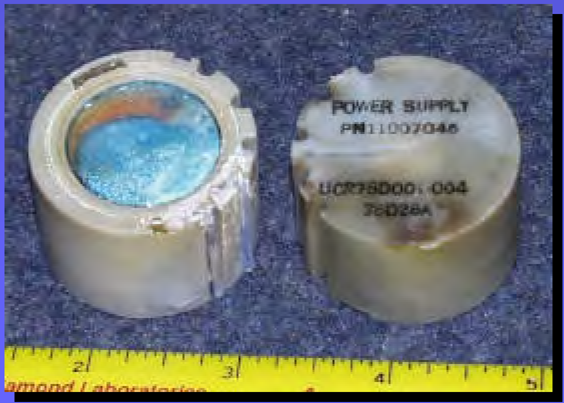
PS115 Section



PS115: Problems Detected

- Production began in 1978
- Five years later, leakage was noticed in engineering samples at HDL
- Further investigation revealed that virtually every lot produced prior to Nov 1980 contained leaking batteries



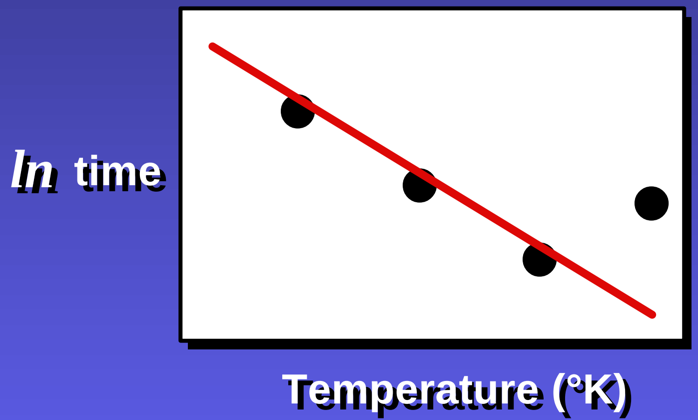


PS115: Investigation Results

- Leakage started earlier and affected a larger percentage of units as temperature increased up to about 60°C (140°F)
- Beyond 60°C, incidents of leakage decreased sharply, essentially reaching zero at about 71°C (160°F)
- Methylene bromide fueled a complex series of reactions with the other reservoir materials
- Above 71°C, increased solubility of copper salts prevented the unique circumstances that caused pitting corrosion and leakage
- High-temp bake-out of reservoir was initial “cure”

A Better Approach

- Store at at least three temperatures
  - determine reaction rates
  - detect changes in behavior
- Use analytical chemistry and optical techniques to measure physical changes
- Determine what is happening, and how fast



Change in Chemistry

- Lead is pretty much history in munitions batteries
  - Environmental concerns, lack of business
  - Non-availability of some critical materials
- Lithium Oxyhalides are systems of choice
  - Good history with single-cell, glass reservoir (barrier munitions, M762 time fuze)
  - Starting to see metal reservoirs in artillery applications (MOFA)
  - Missiles use metal reservoirs
    - 10-year shelf life?
    - Treated better?

Concerns with Oxyhalide Electrolytes

- Very few materials are compatible
- *Extremely* moisture sensitive
  - Reaction products include HCl, SO_2, Cl_2, H_2SO_4
- Some additives/constituents can cause problems
- Can also be affected by light and heat
- Issues have been raised on several current programs
  - Solid forming in electrolyte?

From the Literature

- *Generally speaking*, several metals exhibit good corrosion resistance to neutral electrolytes ($LiAlCl_4$ in thionyl chloride and sulfuryl chloride)
- Using $AlCl_3$ creates a much more corrosive environment (acid electrolyte)
- Of concern in metal containers:
  - heat-treated (welded) areas
  - stressed areas
  - crevice regions
  - metal couples

Some Lessons

- General information is nice, but best to evaluate specific designs
- Great care is required to collect and prepare samples for analysis
- Electrolyte additives should be thoroughly studied prior to implementation

Recommendations

- Start thorough compatibility studies as early as possible, using representative hardware
- Assume studies will take some time and careful planning and execution; quick results likely to be bad news
- Need to understand potential failure mechanism(s): PS115

ARL's Contribution

- Retain in-house Government expertise
- Support contractor's development efforts
- Conduct complementary testing and analysis
- Work to ensure the product meets the Government's requirements
  - Need to independently assess the proposed technology
  - Government needs to be an educated buyer

Miniature Thermal Batteries for Low–Current Applications

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Army Research Laboratory
17 April 2001

Present Thermal Battery Technology

1. Thermal batteries have been miniaturized for high–current (1 to 4 A/cm^2) operation.

- Nuclear applications.
- Missiles.
- Artillery applications (high spin).
- Volumetric energy density of high spin thermal batteries has been increased by a factor of 8 since FY96 at ARL.

2. High reliability and mature technology could be applied to low–current operation.

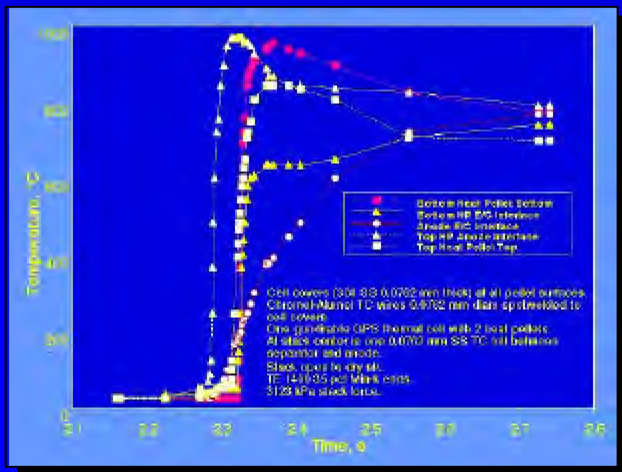
Low–Current Thermal Battery Goals

- Small size. 0.1 cm^3 – (0.2 in. dia. x 0.2 in. tall)
  0.8 cm^3 – (0.4 in. dia. x 0.4 in. tall)
- Low current. (50 μA to 20 mA, 3 to 10 V)
- Moderate lifetime. (5 to 10 minutes)
- High reliability. (0.9990 at 95% confidence)
- Long shelf life. (20 years)

Miniaturization Method

1. **Heat transfer is a major problem.**
   - **High temperature molten salt electrochemistry.**
   - **Control heat loss rates.**
   - **Control cell heat generation rates.**

2. **Optimize a low–current battery design.**
   - **Calculate thermal lifetime.**
   - **Operating cell temp. range is 325 to 700° C.**
   - **Ambient temp. range is -43 to +63° C.**
   - **4 thermal cells (7.2 V to 5.4 V at 1.5 mA).**



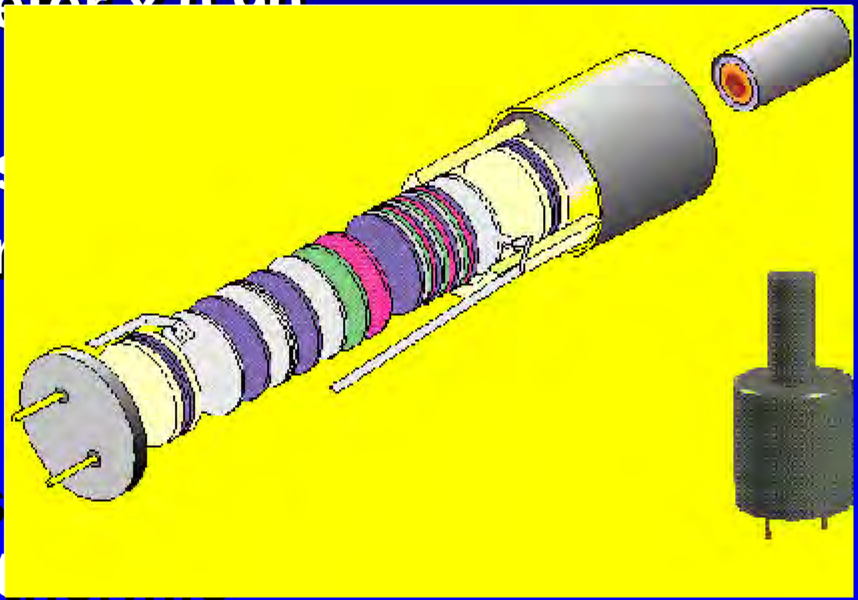
Heat Transfer Considerations

1. Thermal conductivities could be reduced by a factor of 8 in production thermal batteries.
   - Improved commercial insulators.
   - Improved chemical processing.
   - Use of gas gettering agents.

2. Construction improvements facilitate miniaturization.
   - Single pellet thermal batteries.
   - Control of heat generation.
   - New electrochemical systems.

Present Miniaturized Thermal Battery

- Volume 9.38 cm^3.
  - case is 0.90 inch diame
    inch long
  - thermal cell diameter i
- Energy density at 1.5 mA d
  0.090 Wh/l.
  - 320 s thermal lifetime
- Present battery pellets, gas
  environment, chemical exot
  reactions.
- Cells contain 72.0 times required electrochemical capacity at 1.5 mA drain.



Miniaturized Thermal Battery (2 to 5 Years)

- Volume 0.552 cm^3.
  - case is 0.35 inch diameter x 0.35 inch long
  - thermal cell diameter is 0.2 inch
- Energy density 1.61 Wh/l at 1.5 mA drain.
  - 338 s thermal lifetime
- Multi-pellet construction, improved gas environment from improved chemical processing, some gas gettering.
- Cells contain 3.41 times required electrochemical capacity at 1.5 mA drain.

Miniaturized Thermal Battery (5 to 10 Years)

- Volume 0.129 cm^3.
  - case is 0.20 inch diameter x 0.25 inch long
  - thermal cell diameter is 0.12 inch
- Energy density 11.5 Wh/l at 1.5 mA drain.
  - 566 s thermal lifetime
- Single pellet battery construction, improved chemical processing and gas gettering, along with increased internal heat generation.
- Cells contain 1.10 times required electrochemical capacity at 1.5 mA drain.

Energy and Power Densities

	Present Thermal	Thermal 2 to 5 Years	Thermal 5 to 10 Years	Present SDF Battery
Wh/l	0.090	1.61	11.5	0.744
Wh/kg	0.061	0.738	4.19	0.159
W/l	1.01	17.1	73.4	9.92
W/kg	0.685	7.85	26.6	2.11
cm^3	9.38	0.552	0.129	0.128

Thermals operate at 7.2 to 5.4 V and 1.5 mA.

Lifetime and Pulse Characteristics

	Present Thermal	Thermal 2 to 5 Years	Thermal 5 to 10 Years	Present SDF Battery
Life (s)	320	338	566	270
Pulse (kW/l)	2.10	8.97	13.8	0.027
Over-design (Ratio)	72.0	3.41	1.10	

Thermals operate at 7.2 to 5.4 V and 1.5 mA.

Thermal Battery Starters Require Miniaturization

1. Inertial White starter is 0.312 inch diameter x 1.05 inch long (1.32 cm^3 and 6.5 g).

2. Inertial M42 C-1 primer is 0.175 inch diameter x 0.120 inch long (0.0473 cm^3 and 0.20 g).

3. Inertial M42 C-1 primer starter is similar in size and mass to the White starter. **One primer starter might be used for several inertial primers.**

4. Electrical squib is 0.205 inch diameter x 0.185 inch long (0.100 cm^3 and 0.56 g).

Conclusions

1. Small thermal batteries can be made the size of present thermal battery squib initiators.

2. Thermal batteries the size of present squib initiators can operate for several minutes at μA and mA current drains.

3. Low–current thermal batteries can be used in miniaturized fuzes where they can supply large pulse currents.

The Evolving Fuze
or
When a Fuze is not just a Fuze

Colonel Richard Hulmes
AD Land Manoeuvre Division
UK Defence Ordnance Safety Group

DELIVERING FUZE SAFETY

NATO SAFETY STANDARDS

AC310 Sub Group 2

FUZES

SAFETY THE GENERAL BUSINESS CASE

- OBVIOUS - ENVIRONMENTAL AND PUBLIC PRESSURE
- POLITICAL WILL (eg LANDMINES)
- LEGISLATION - UK HSWA 1974 s6(1)
- LITIGATION

SAFETY THE DEFENCE BUSINESS CASE

- CONFIDENCE IN EQUIPMENT
- PROTECT OUR SERVICE PERSONNEL
- STANDARD SAFETY TESTING
- INTERNATIONAL COMPATIBILITY
- OFF THE SHELF PROCUREMENT

NATO International Safety Standards

STANAG 4187

Fuzing Systems - Safety Design Requirements

AOP 16

Fuzing Systems - Guidelines for STANAG 4187

AOP 42

Integrated Design Analysis for Munition Initiation Systems and other Safety Critical Systems

Definitions

Fuzing System (STANAG 4187)

A system designed to:

- Provide as a primary role safety and arming functions in order to preclude munition arming before the desired position and time
- Sense a target or respond to one or more prescribed conditions, such as elapsed time, pressure or command
- Initiate an explosive train in a munition

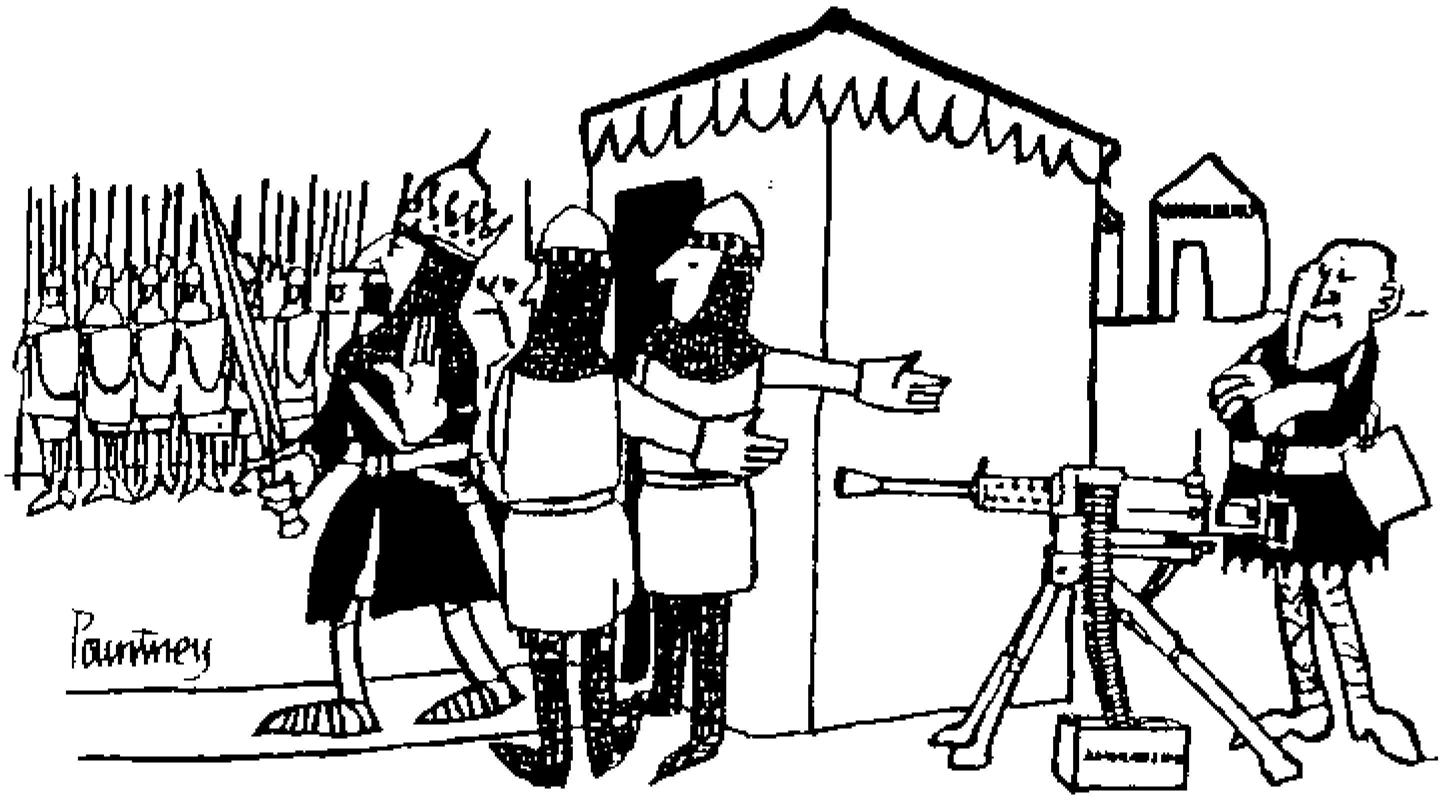
FUNDAMENTAL SAFETY DESIGN REQUIREMENTS - STANAG 4187

9.1.1 Fuzing systems shall include at least two safety features, the operation of which are, wherever possible, functionally isolated from other processes within the munition system ...

Processes which may use but are not considered part of Fuzing systems in normal operation

- Course Correction
- Flight Termination*
- Remote Control (sensor)
- Anti - Dud
  - (Unexploded Munition = Landmine)
- Demilitarisation/Disposal*
- ?

DOSG
DEFENCE ORDNANCE SAFETY GROUP



Tell him that unless it complies with STANAG 4187
I don't care how good it is!

Some Principles

- Must not compromise intrinsic safety
- Add-ons should be independent
- Novel solutions considered - supported by Design Analysis
- Use STANAG 4187, AOP 16 & 42
  - ➔ National Safety Approving Authority

Concept Approval - Recommendations

- Hazard Analysis
- Fault Tree Analysis
- Design Logic
- Integrated Design Analysis (AOP 42)

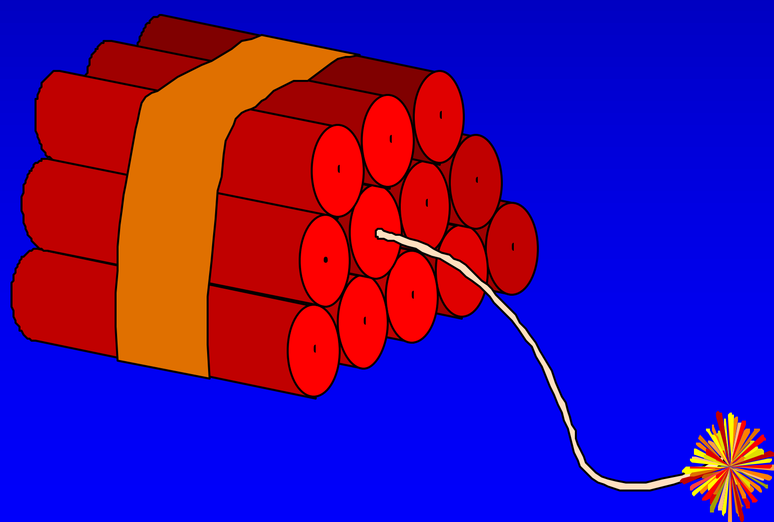
Colonel Richard Hulmes

- dosglm-ad@dpa.mod.uk

Major David Parrott

- dosglm3a@dpa.mod.uk

Any Questions?



FMU-160B: 105mm PROXIMITY FUZE FOR THE AC130 GUNSHIP

Bob Hertlein, Dave Lawson

KDI Precision Products, Inc.

Telly Manolatos

Electronics Development Corp

KDI Precision Products, Inc.

An ISO 9001 Registered Company

http://www.kdi-ppi.com

Presentation Outline

- Application
- Need for Improved Proximity Fuze
- Design Goals
- Design Approach
  - RF Front End
  - Signal Processor
  - Battery
  - S&A

Application

- **AC-130 Gunship**
  - ✧ **Air Force Special Operations Command (AFSOC)**
  - ✧ **Modified M137 105mm Cannon**

Need for Improved Proximity Fuze

- High Fragmentation (HF) Version of HE M1 (MOD) Cartridge
  - Maximum effectiveness requires precise HOB regardless of target reflectivity and approach angle
  - Proximity fuzes currently available are not optimized for the HF round
    - Wide HOB variation
    - Average HOB not optimum
    - Insufficient reliability

Design Goals

- Tight HOB Control
  - Nominal HOB = 15 ft
- Impact Back-up Mode
- Highly Reliable
- Surface Mount Technology
- Maximum Commonality to Existing Designs
  - Proven Reliability
  - Reduced Cost

Design Approach

- RF Front End
- Signal Processor
- S&A
- Battery

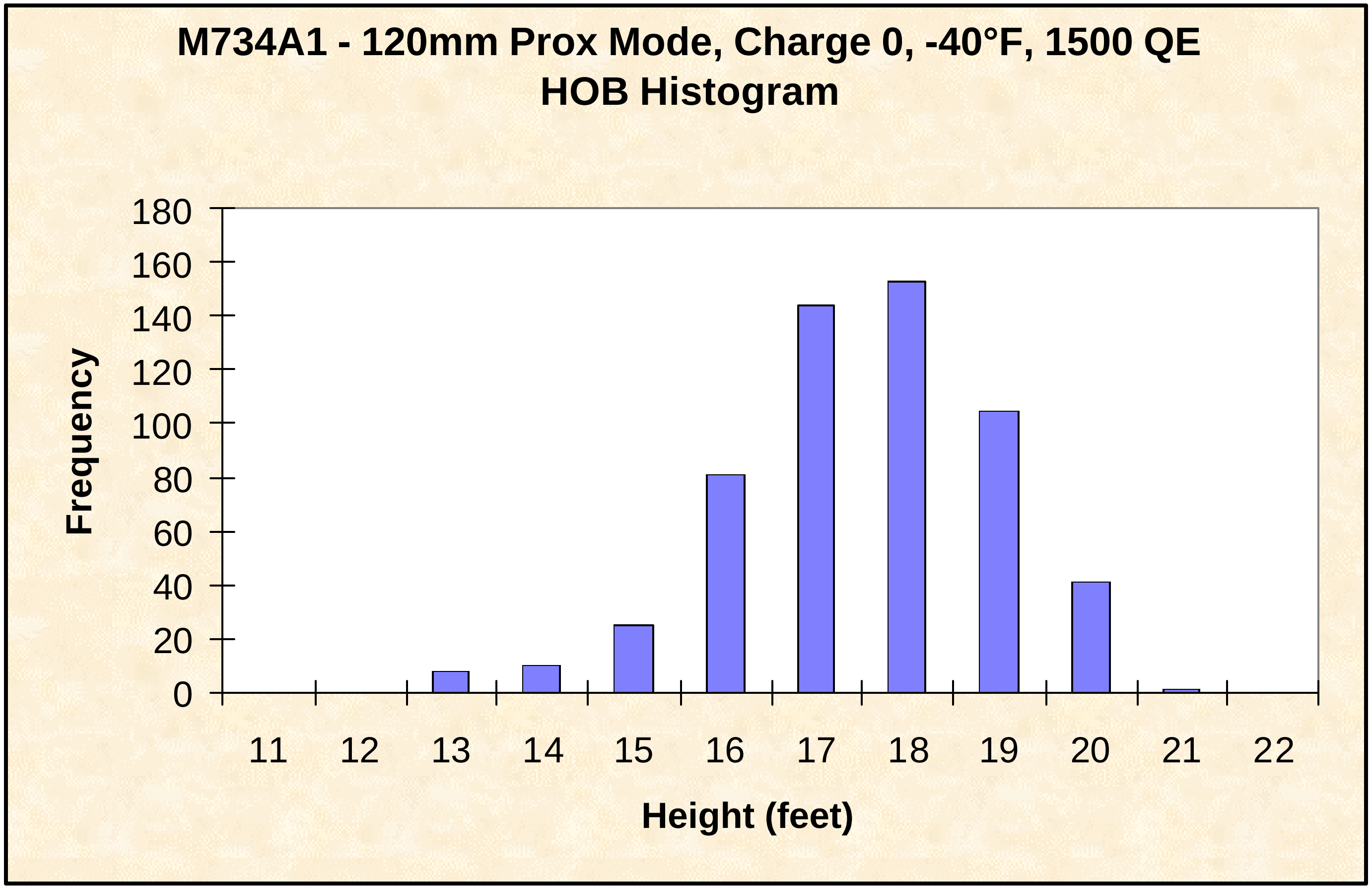
RF Front End

- Based on Highly Successful M734A1 Multi-Option Fuze for Mortars (MOFM)
  - MMIC Transceiver
  - Circular Patch Antenna
    - Wide Bandwidth
    - Broad Coverage
  - Additional IF Gain Stage

Signal Procesor

- Same Signal Processor as the M734A1 MOFM
- Utilizes DDR Technology
  - Accurate HOB Control
  - Robust Anti-jamming Performance
- Highly Integrated
  - Single Chip Solution
  - High Reliability
  - Low Cost

TYPICAL PERFROMANCE



S&A

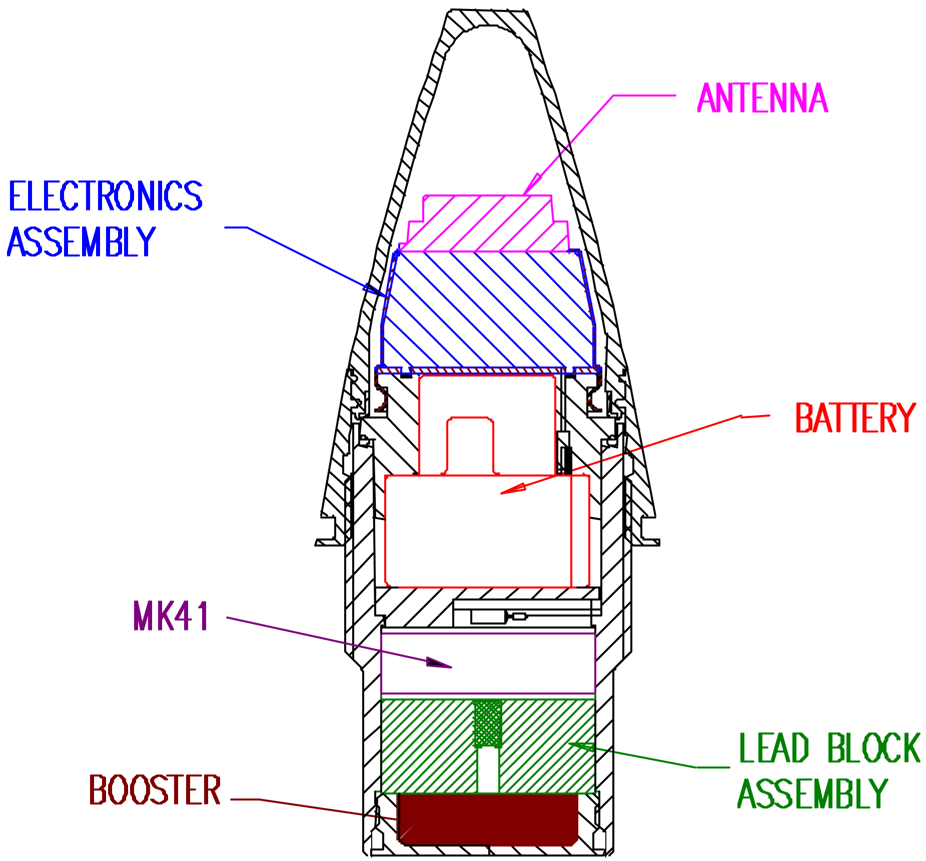
- MK41 is a Qualified Design
- Low Cost
- Performance Parameters:
  - Setback g Level: 26,000 g
  - Spin Rate: 410 rps
  - Velocity: 3075 ft/sec

Battery

- Manufactured the Netherlands by Thales Munitronics
  - Formerly Signaal USFA
- Chemistry: Lithium
- Proven Design for Artillery
- Performance Parameters:
  - Operational Life: 150 seconds min
  - Current: 150 mA
  - End of Life Voltage: 5.5 Volts min
  - Rise Time: 100 mSec max
  - Required Setback: 2000 g's min
  - Required Spin: 2500 rpm min
  - Operating Temperature: -40F to +145F

Photo of FMU-160/B

Summary



- **ACCURATE**
- **RELIABLE**
- **AFFORDABLE**

KDI Precision Products, Inc.

An ISO 9001 Registered Company

Common Precision Munitions Safety & Arming Device

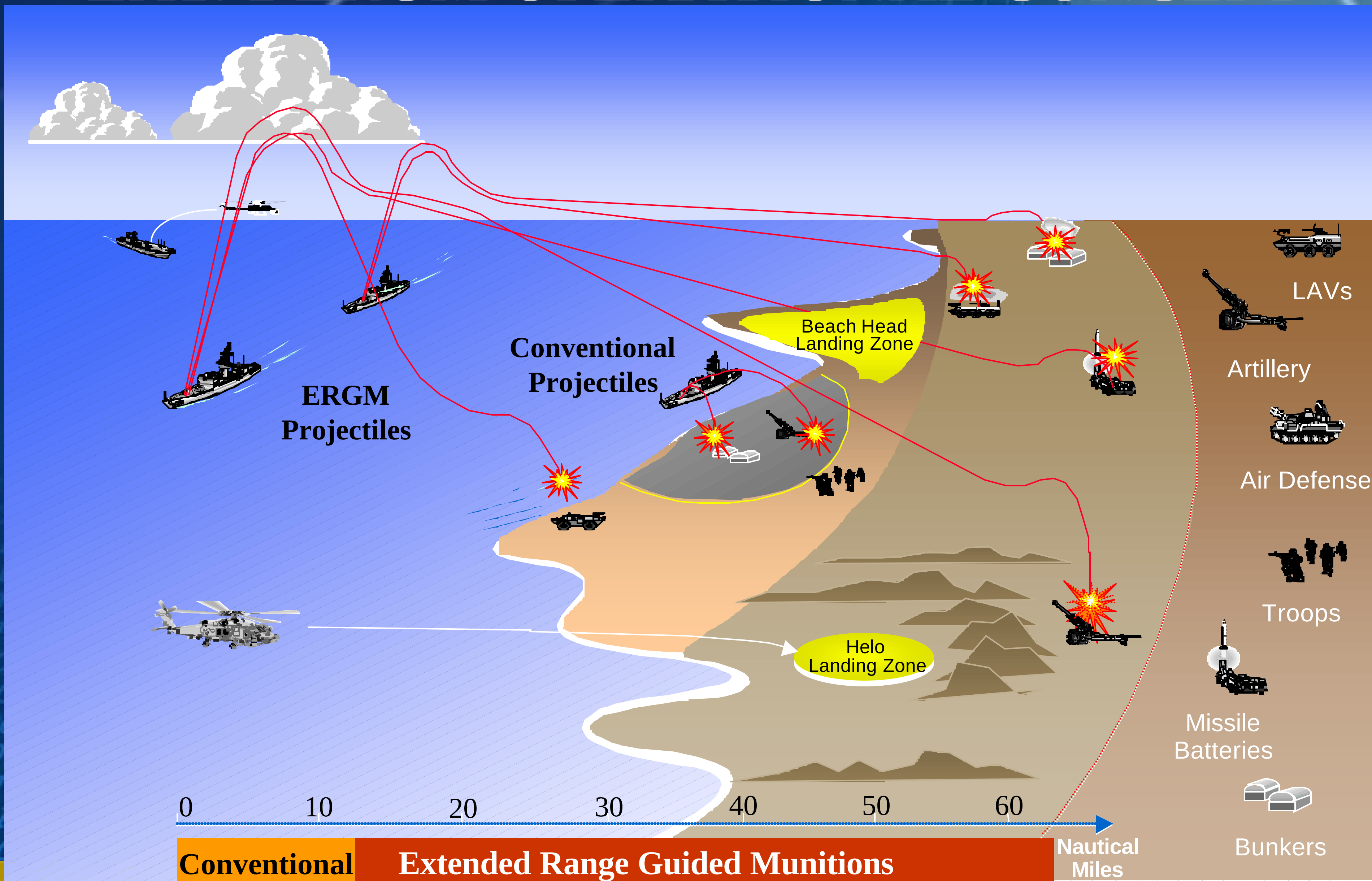
Presented By: Mr. Richard Dirks

www.kdi-ppi.com

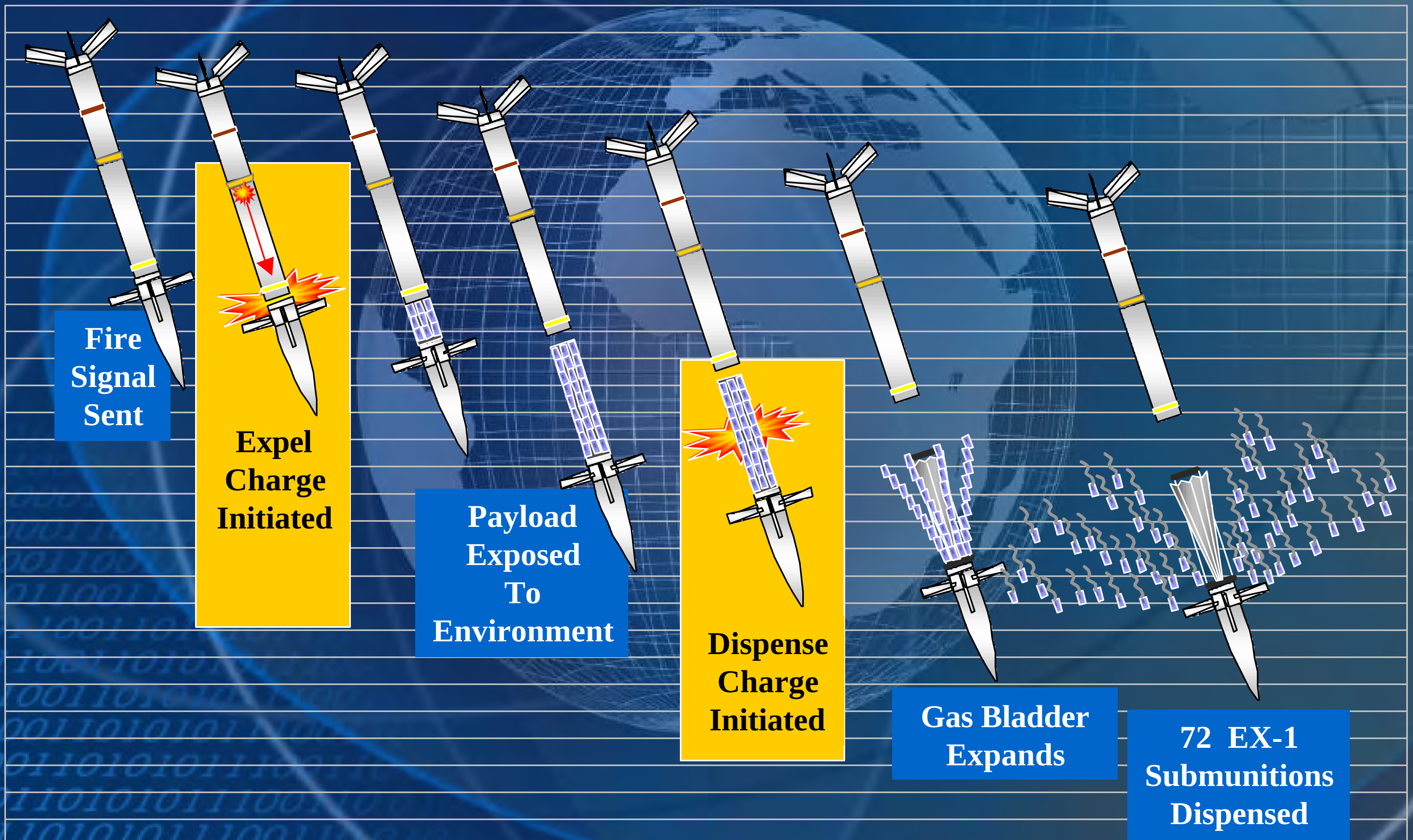
OUTLINE

- ERGM System Overview
- ERGM Payload Sequence
- XM982 System Overview
- XM982 Payload Sequence
- ERGM S&A Location
- XM982 S&A Location
- S&A Technical Requirements
- MIL-STD-1316D Compliance
- S&A Mechanical Design
- S&A Electrical Design
- S&A Integration
- S&A Event Sequence, Outputs, and Capabilities
- Program Test Results / Milestones

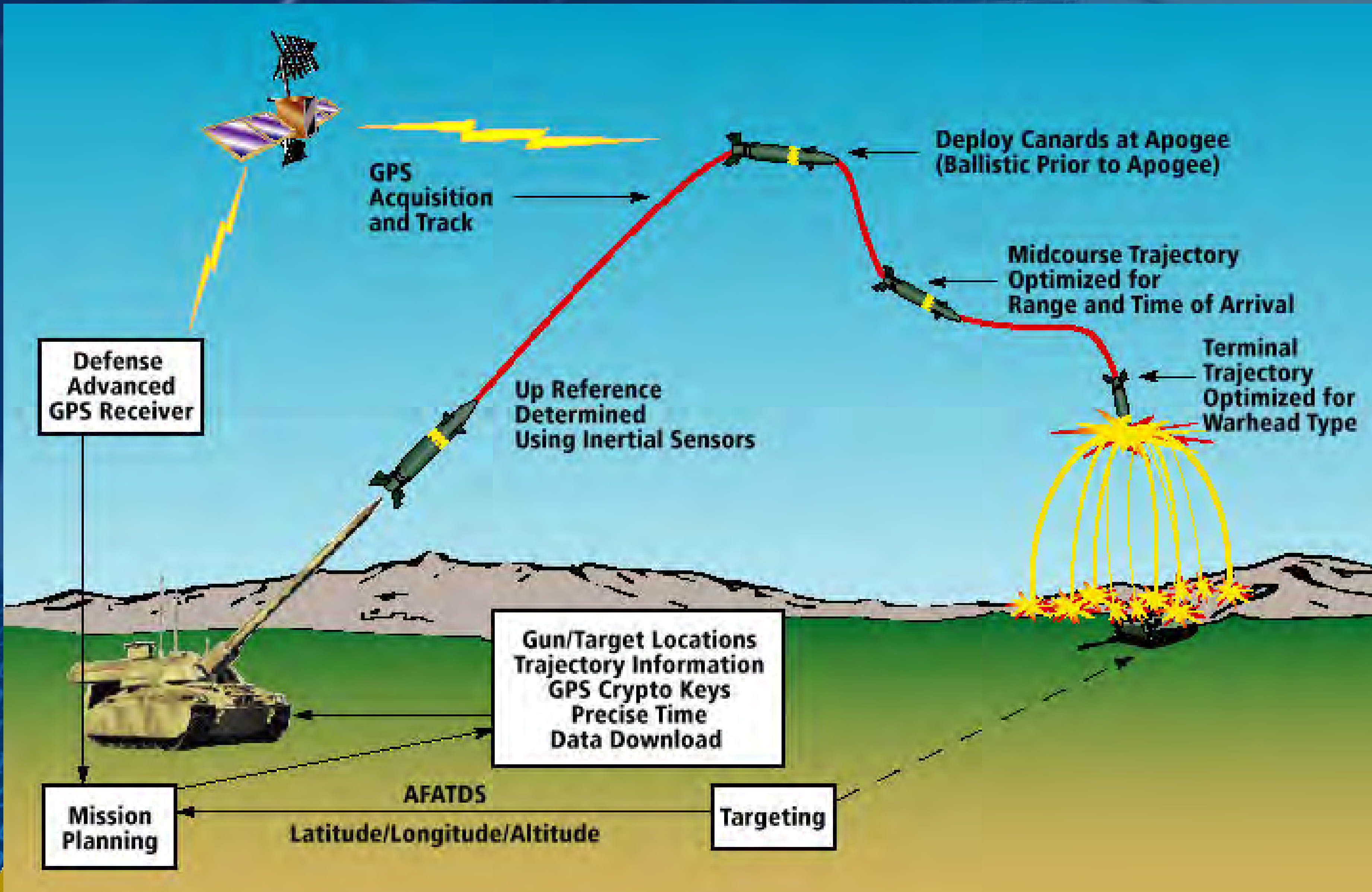
EX171 ERGM OPERATIONAL CONCEPT



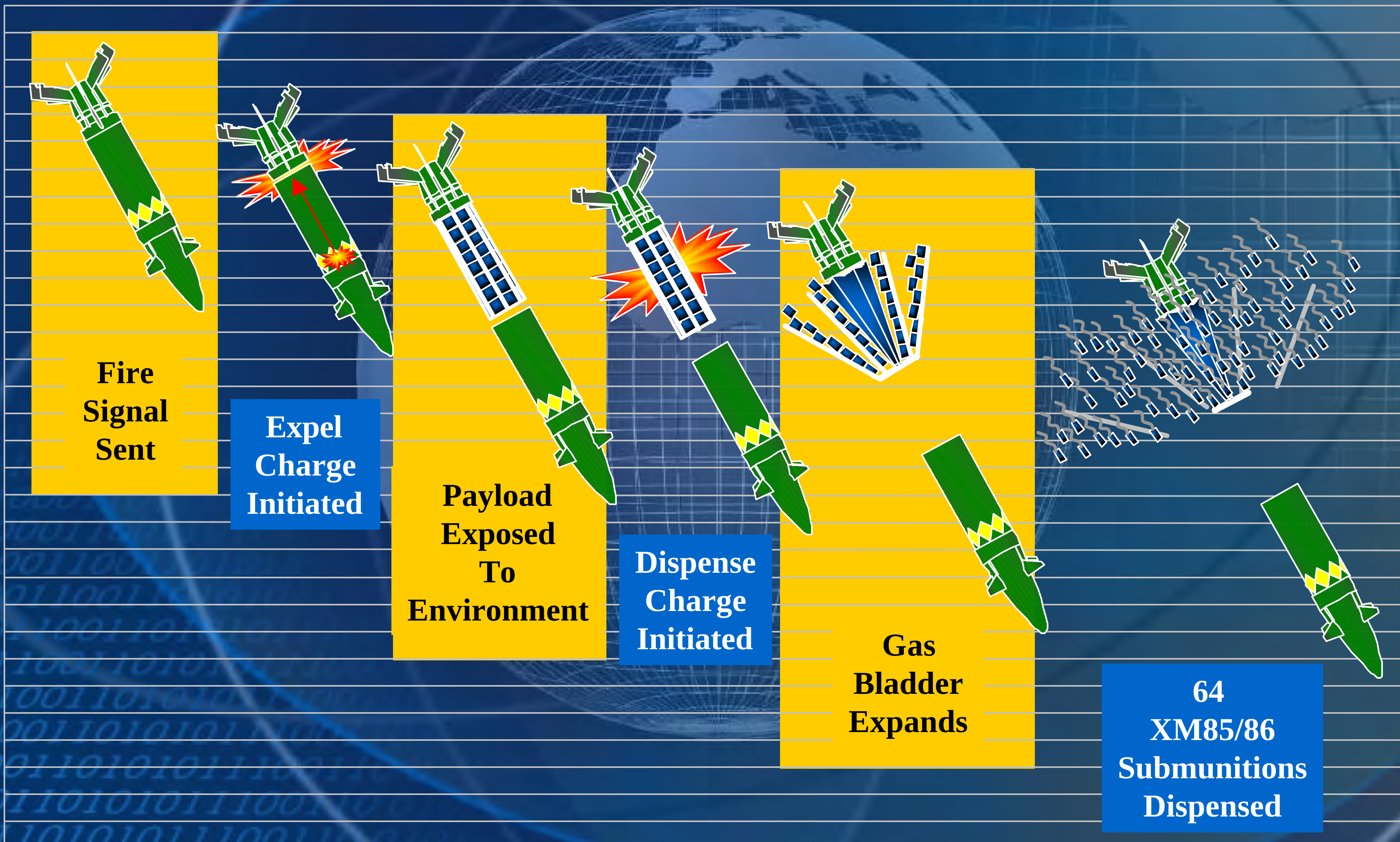
ERGM SUBMUNITION EXPEL & DISPENSE



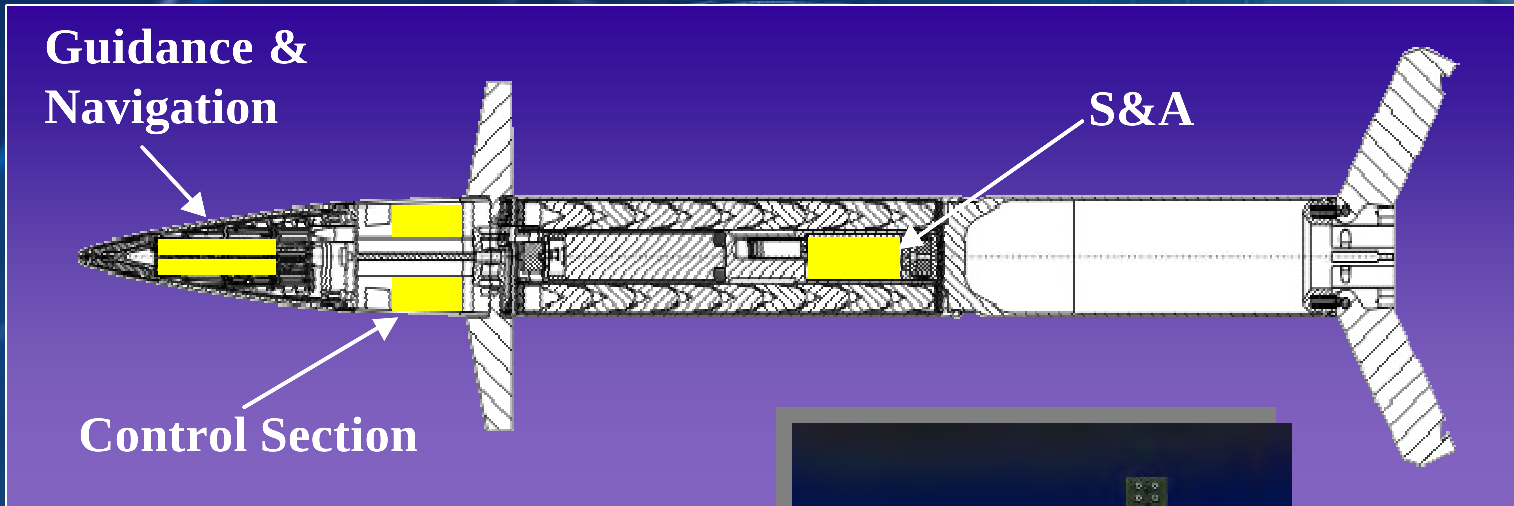
EXCALIBUR OPERATIONAL CONCEPT

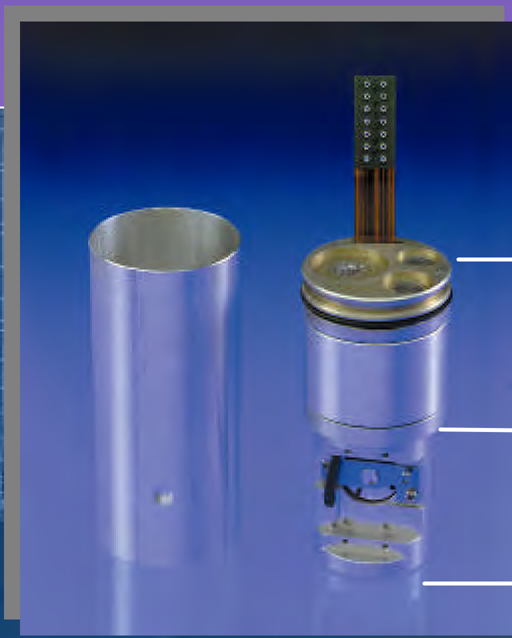


EXCALIBUR SUBMUNITION EXPEL & DISPENSE

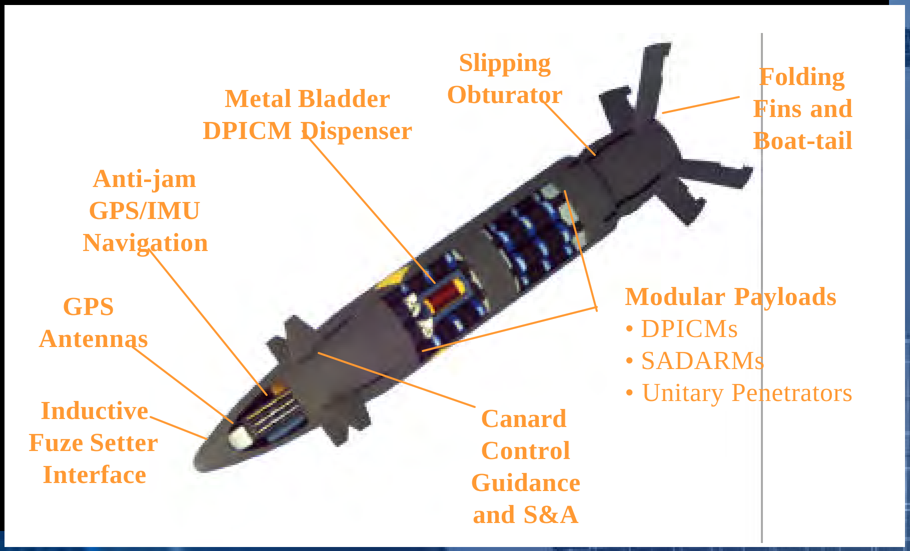


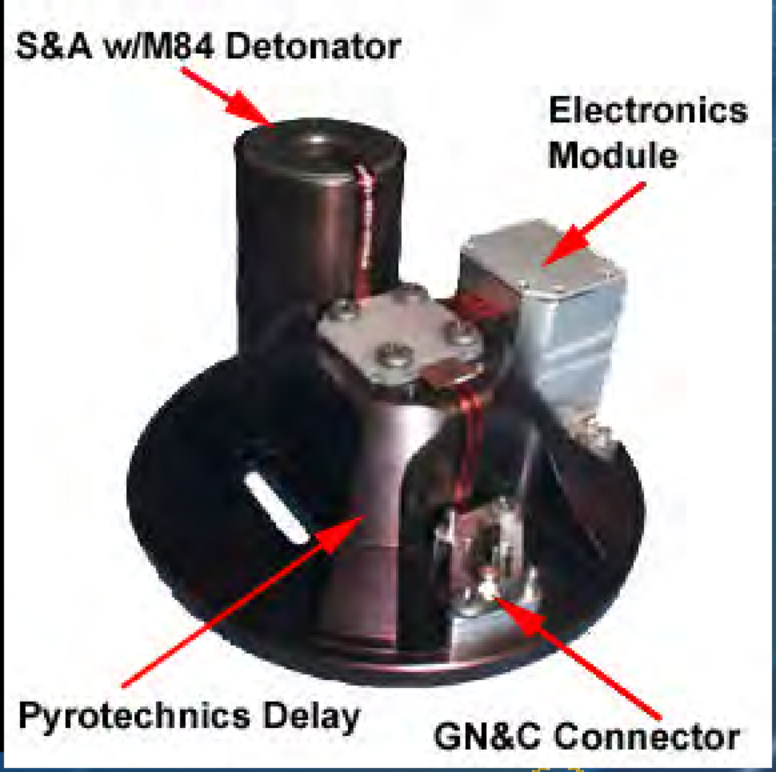
ERGM EX87 S&A DEVICE AND LOCATION





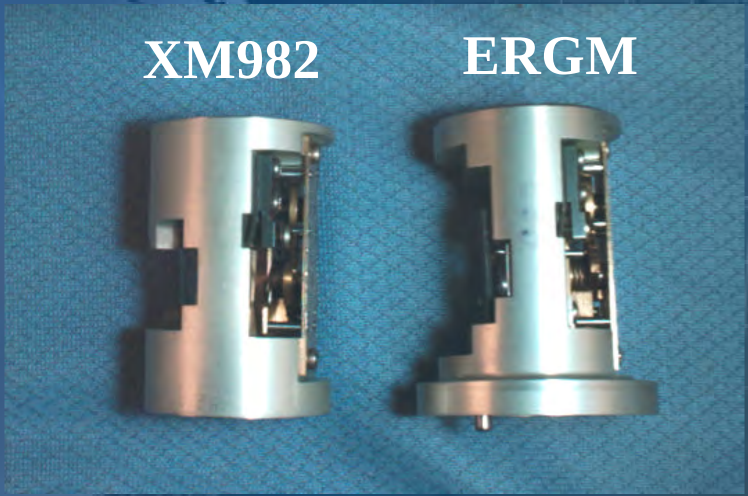
XM982 S&A DEVICE AND LOCATION





S&A REQUIREMENTS

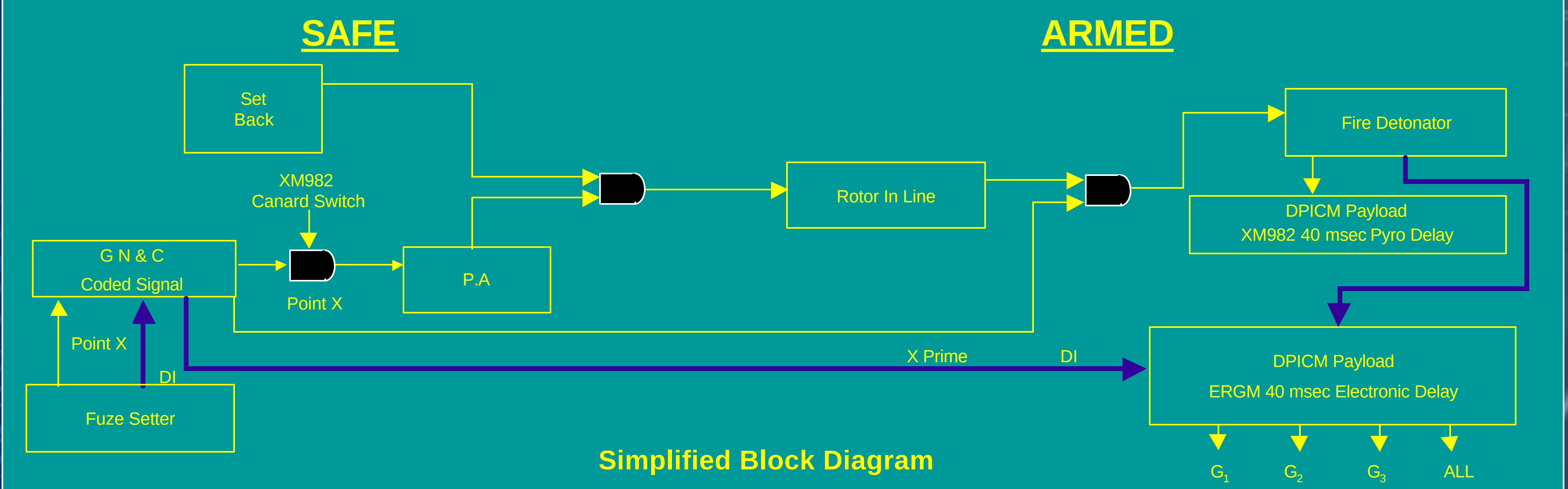
- Projectile Application
  - All Arm - 1,250 G's
  - No Arm - 300 G's
- No Spin
- Interface With GN&C
- MIL-STD-1316D Compliant
- Seal Against "Expel" Pressure
- ERGM Unique
  - Support "Dispense" Forces
  - User Selectable Output
  - Autonomous "End Game" Operation



MIL-STD-1316D COMPLIANT

ERGM/XM982

- Two Independent Locks
  Set Back
  GN&C
- Sequence Dependent
- Enhanced Overhead Safety
- Anti-Malassembly Feature
- Launch Derived Rotor Drive Energy
- Selectable Output (ERGM Only)



Simplified Block Diagram

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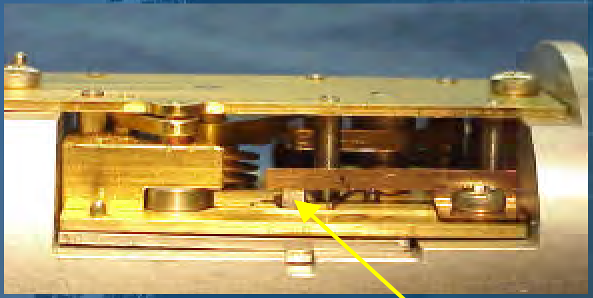
S&A MECHANICAL DESIGN APPROACH

- Mechanical S&A Design Approach
  - Modified MK18 S&A
    - Higher G Loads
    - AFT Detonation Output
    - Switches Indicate Rotor Position
    - Integrated Electronics Control
  - Three (3) Leaf Set Back Mechanism

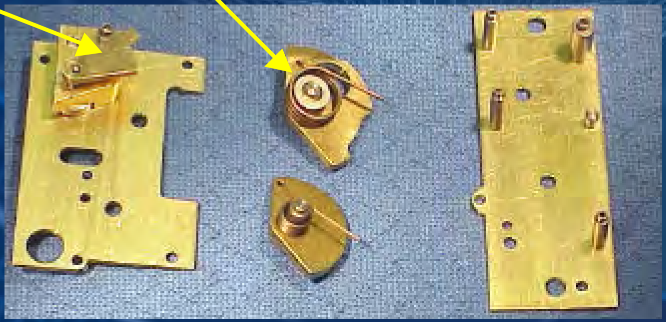
Second Rotor Lock (Safe)



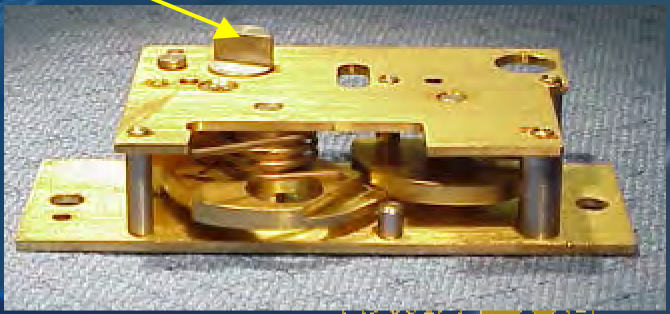
Rotor Lock (Arm)

Leaf Lock

Rotor Drive Spring



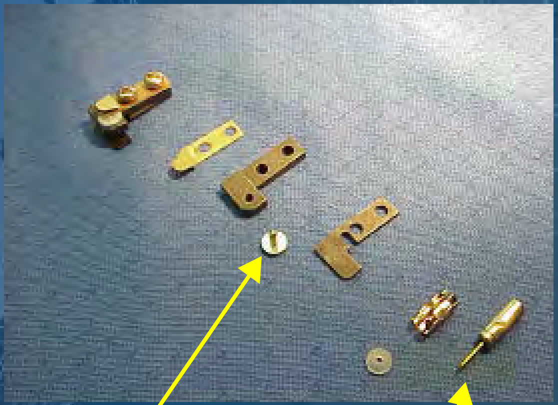
First Rotor Lock (Safe)



S&A ELECTRICAL DESIGN APPROACH

- S&A Electronics
  - RS232 Serial Communication Link
  - Codeword Controls Function

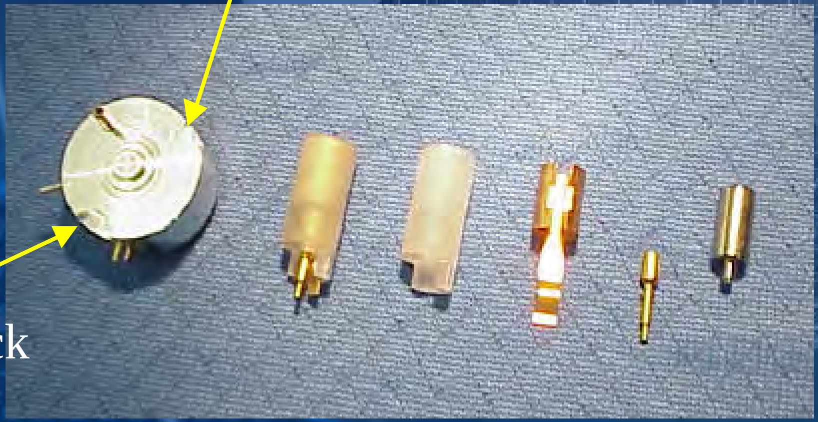
GN&C
Second Rotor Lock W/PA



Safety Button

Piston Actuator

Second Safety & Arm Lock

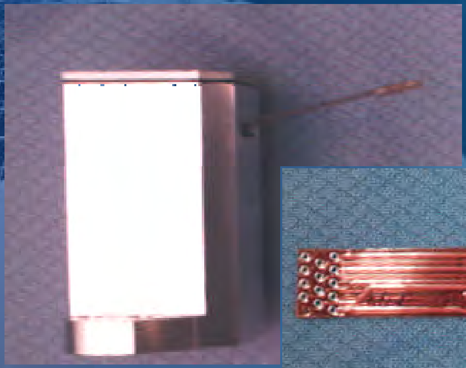


Set Back Lock

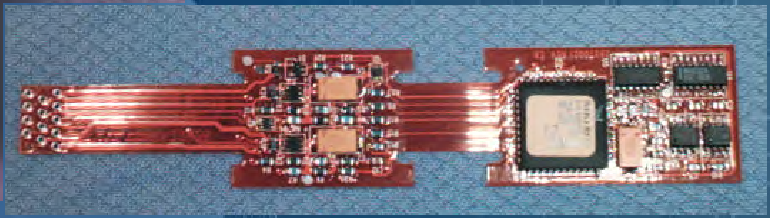
Rotor W/Switches & M84 Detonator

ELECTRONICS PACKAGE

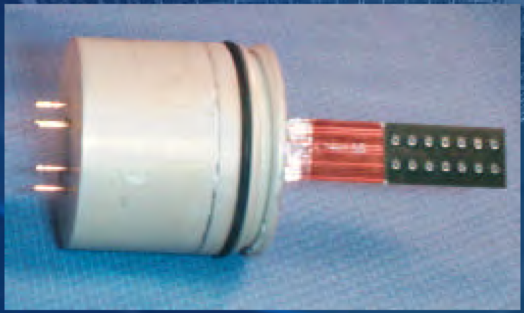
- Electronics Design
  - Flexible PWB
  - SMT
  - Glass Bead Fill
  - Mosfet Circuitry
    - Independent Timer (10 sec)
    - FPGA
  - Energy Storage
    - Autonomous Operation
    - Two Stage Timed Function



XM982



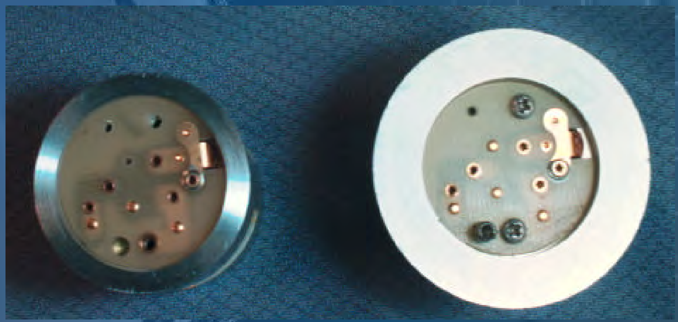
ERGM



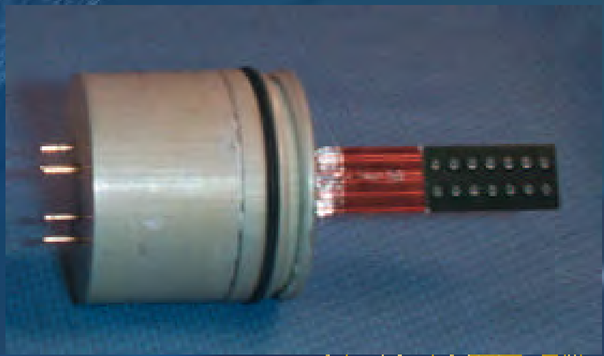
S&A OUTPUTS

- Energetic
  - M84 Electric Detonator Initiates Expel Charge
    - Solder Sealed Enclosure
    - Platinum Bridgewire
- ERGM Dispense Module
  - Initiate Cartridge Primers (44 magnum, 45-70, and 10 gauge)
- XM982 Dispense Module
  - Pyrotechnic Delay

XM982 ERGM



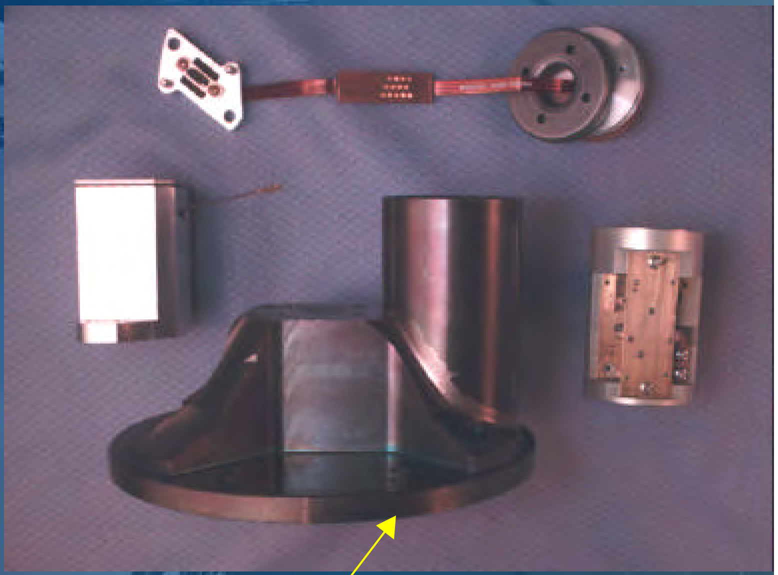
ERGM



S&A INTEGRATION

- Centrally Located
  - Seal Against Pressure
  - Support Structural Load
  - S&A weight Less Than 1 Lb. (Less Expel Liner)
  - Integral Cabling To GN&C

XM982 S&A

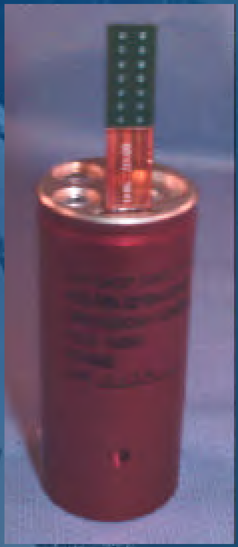


Expel Liner

ERGM EX 87 S&A

S&A DESIGN SUMMARY

- Resulting Capabilities
  - Meets MIL-STD-1316D
  - Interactive W/ GN&C
  - Maximized Overhead Safety
    - Independent Timer
    - Arm Command issued Just Prior to Endgame
  - Variable Outputs ERGM Only



ERGM

XM982

S&A PROGRAM MILESTONES

- ERGM EX 87 S&A
  - Piston Actuator Qualification - May & June '01
  - EX87 S&A Qualification - July thru September '01
- XM982 S&A
  - Completed Design Analysis Phase, Ready for Verification Testing
  - At present - On Hold

Microwave Fuze

INNOVATIVE DIGITAL PROXIMITY FUZE FOR 76/62 mm GUN (Microwave, Programmable)

Otobreda Division

Alenia DIFESA

Companies

SIMMEL DIFESA

Marco BROGI
Maurizio CALEO

Authors

Antonio CARRIERO

45th Fuze Conference, Long Beach, CA, April 16-18 2001

Microwave Fuze

ITALIAN NAVY

awarded the development contract

ALENIA DIFESA

OTOBREDA DIV.

(former OTO Melara)

- computer modeling
- µW sensor
- signal processor
- firing tests

Otobreda Division

Alenia DIFESA

SIMMEL DIFESA SpA

(heritage from Borletti and BPD)

- fuze integration
- impact sensor
- post-impact delay
- battery
- S&A
- pyrotechnic chain

SIMMEL DIFESA

Microwave Fuze

FUZE MAJOR FEATURES

- PROGRAMMABILITY OF OPERATING MODES from the FCS through a setter
- 5 OPERATING MODES
  - PROXIMITY vs SEA SKIMMER (default mode)
  - PROXIMITY vs FIXED WING AIRCRAFT
  - PROXIMITY vs ROTARY WING AIRCRAFT
  - PROXIMITY vs SURFACE TARGETS
  - DELAYED IMPACT vs REINFORCED TARGETS
- 2 BACK-UP MODES (not available if delayed impact is selected)
  - UNDELAYED IMPACT
  - SELF DESTRUCTION

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FUZE MAJOR FEATURES continued

- SAFETY SYSTEM
  - COMPLIANT WITH STANAG 4187
  - SAFE SEPARATION DISTANCE (MECHANICAL ARMING) > 100 m
- OPERATING TEMPERATURE RANGE –31°C ÷ +63°C
- STORAGE TEMPERATURE RANGE –40°C ÷ +71°C

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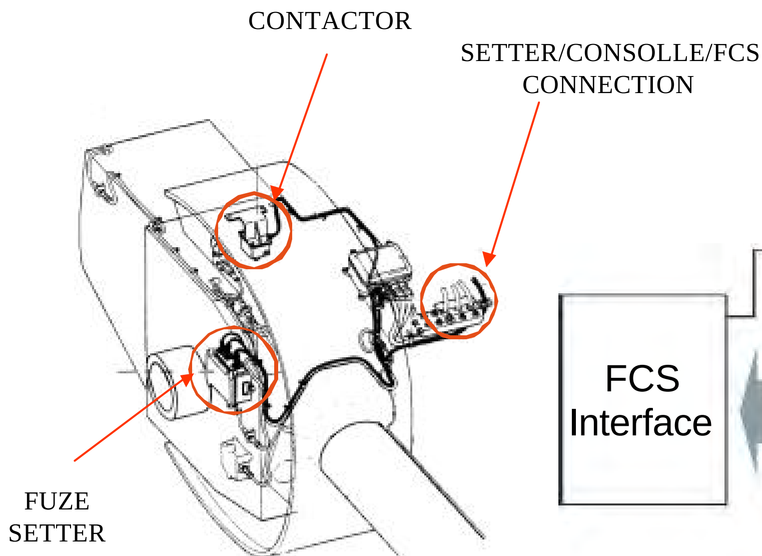
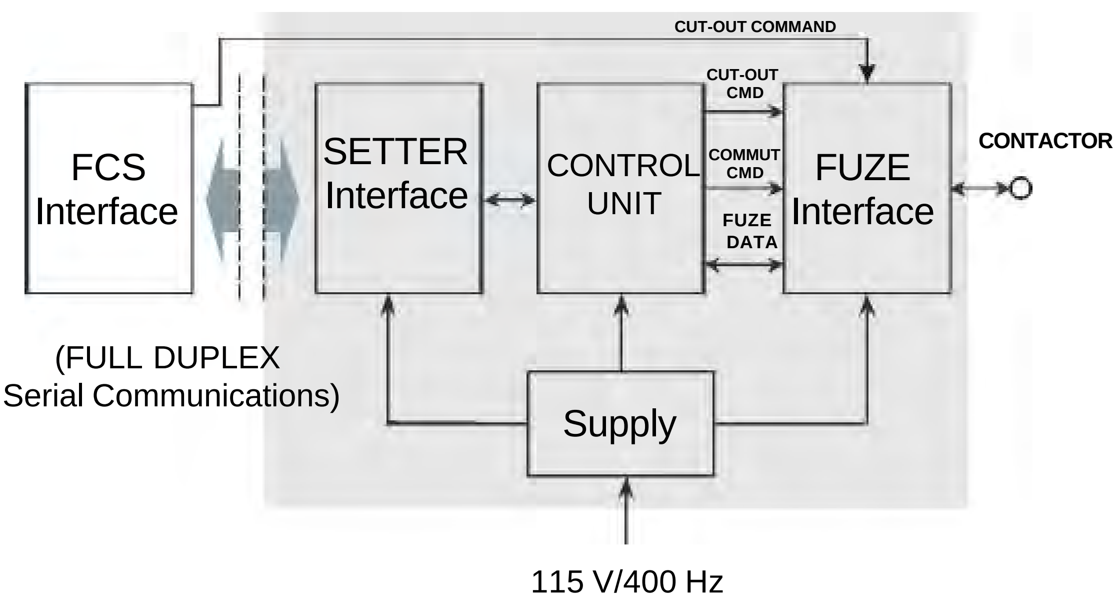
Microwave Fuze

ELECTRONIC SETTING SYSTEM FOR 76 mm PROXIMITY FUZE



INSTALLATION ON GUN ELEVATING MASS

FUNCTIONAL BLOCK DIAGRAM



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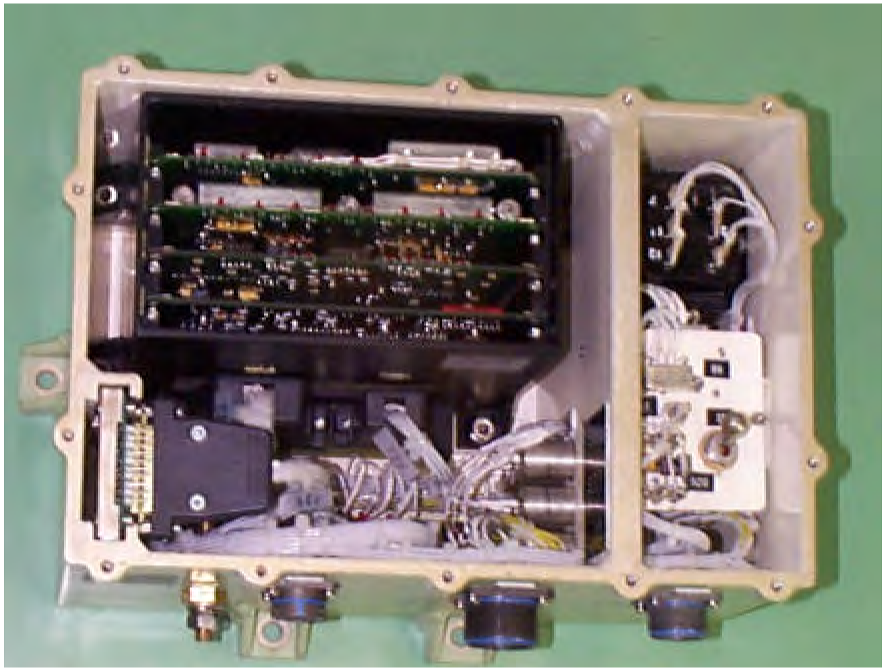
Microwave Fuze

ELECTRONIC SETTER FOR 76 mm PROXIMITY FUZE



- DEVELOPMENT COMPLETED
- 4 SYSTEMS ORDERED BY ITALIAN NAVY FOR NEW FPB's
- 18 SYSTEMS WILL BE INSTALLED ON EXISTING SHIPS

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ELECTRONIC SETTER FOR 76 mm PROXIMITY FUZE

FUNCTIONS

- SELECT THE OPERATING MODE (PROXIMITY/DELAYED IMPACT).
- ENABLE FUZE RECEIVER JUST BEFORE TARGET INTERCEPT.
- OPTIMIZE PROXIMITY PERFORMANCE AGAINST DIFFERENT KINDS OF TARGETS BY SELECTING DEDICATED SOFTWARE.
- RETAIN THE COMPATIBILITY WITH IN-SERVICE FUZES

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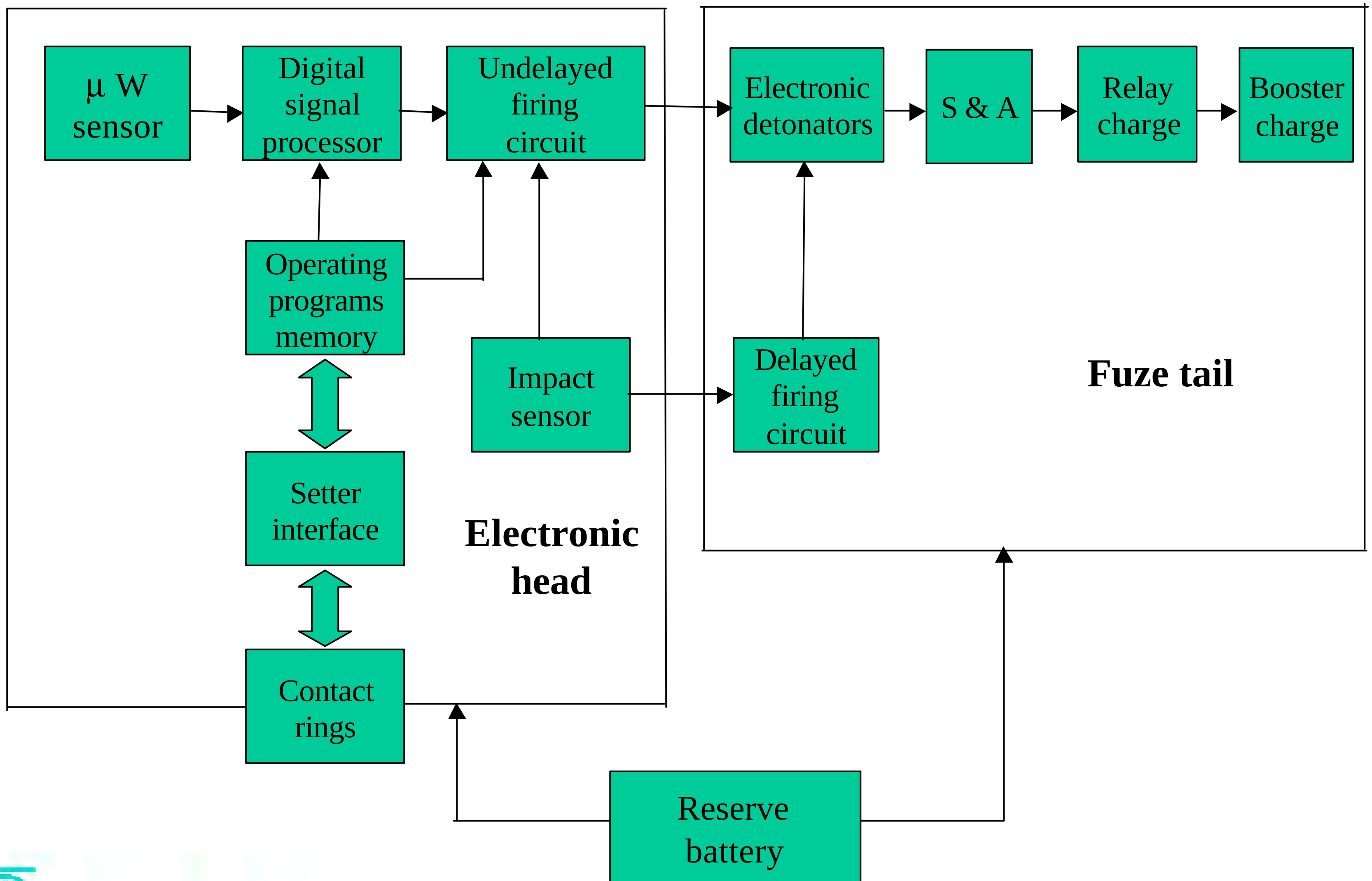

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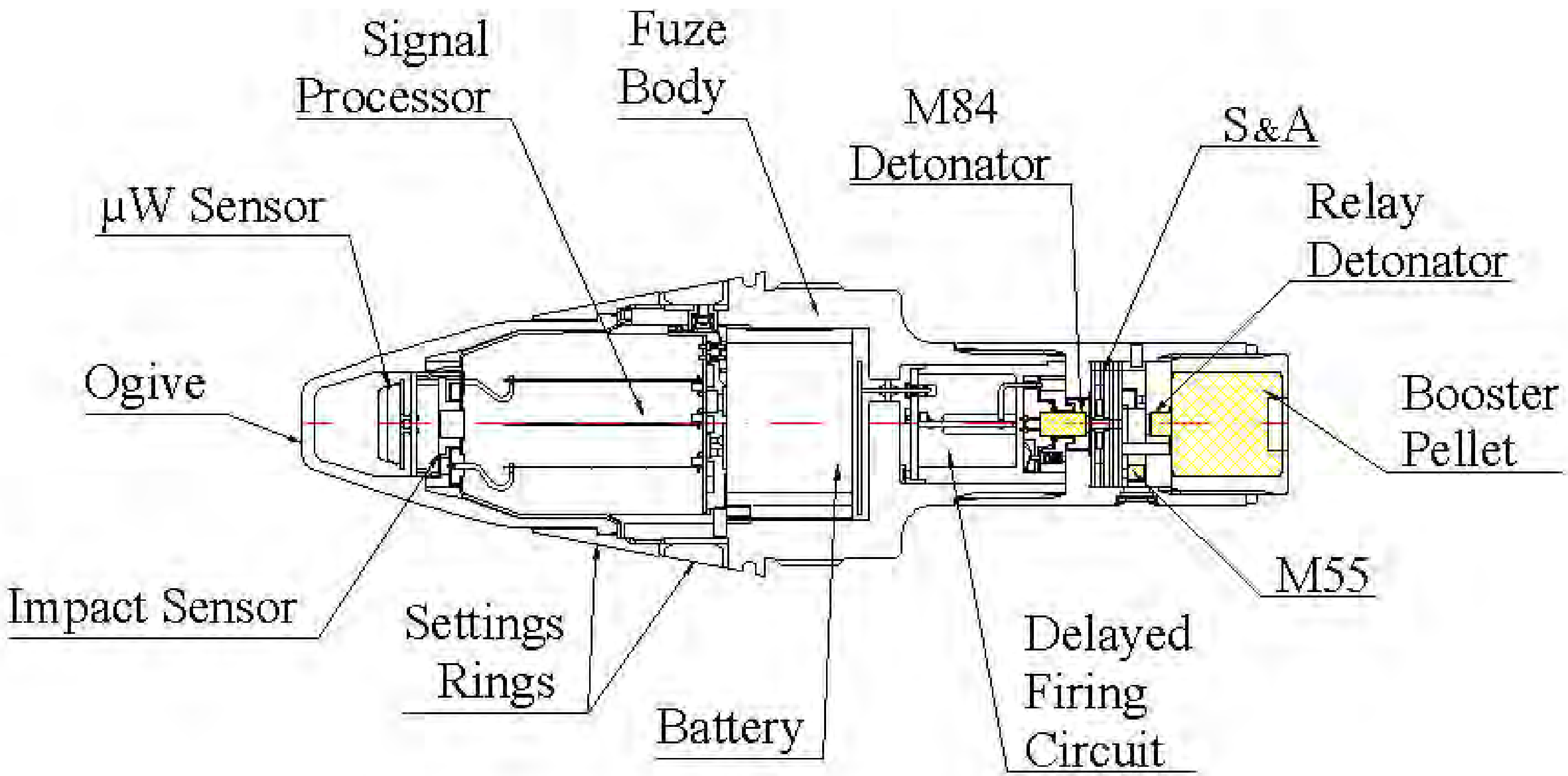
Fuze layout



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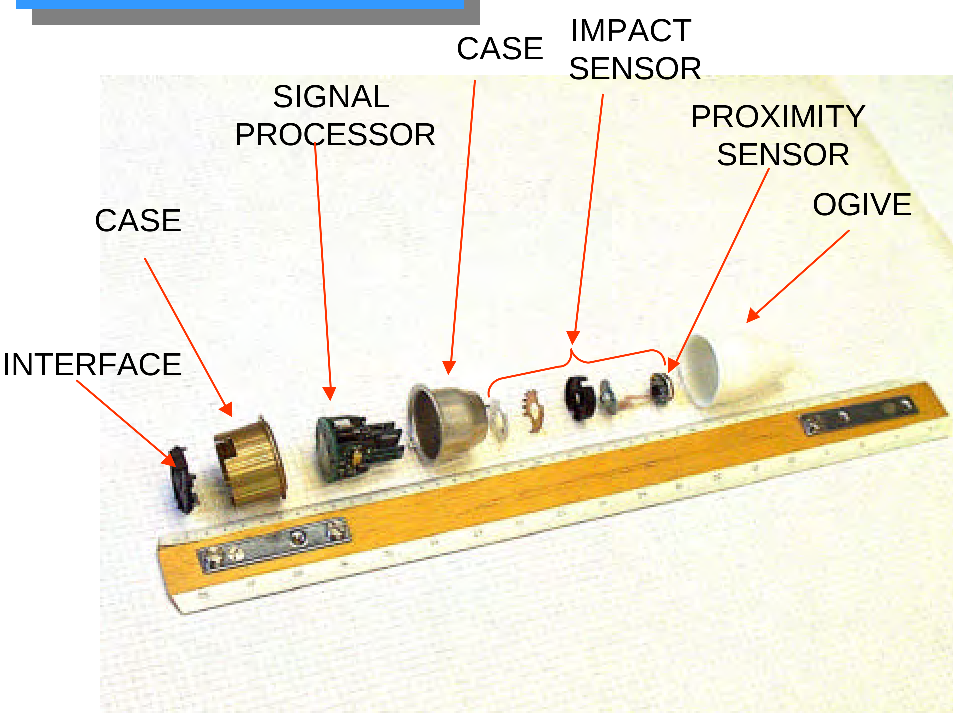
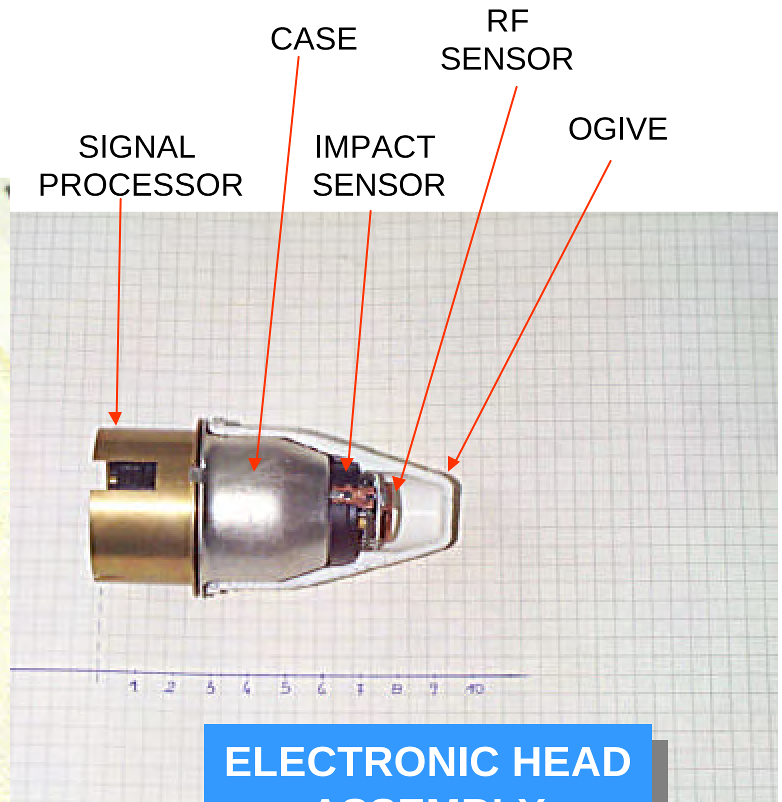
FUZE TECHNICAL DESCRIPTION

ELECTRONIC HEAD BREAKDOWN





ELECTRONIC HEAD ASSEMBLY

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TELEMETRY PROJECTILE FOR IN FLIGHT TEST

USED DURING FUZE DEVELOPMENT

FUZE UNDER TEST

TELEMETRY EQUIPMENT

- 2 A.C. CHANNELS FOR SENSORS SIGNALS (WIDEBAND)
- 2 D. C. CHANNELS FOR POWER SUPPLY CHECK
- 1 TRIGGER CHANNEL FOR DETONATION CHECK

TELEMETRY ANTENNA

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WHY A NEW FUZE

KEY PARAMATERS

- SENSITIVITY RADIUS
- BURST POINT ACCURACY
- ECM & SEA CLUTTER REJECTION

TECHNOLOGIES

- DIGITAL SIGNAL PROCESSING
- MICROWAVE SENSOR
- PROGRAMMABILITY

- IMPROVE 76 mm AIR DEFENSE CAPABILITY
- MAXIMIZE AMMUNITION TERMINAL EFFECTIVENESS

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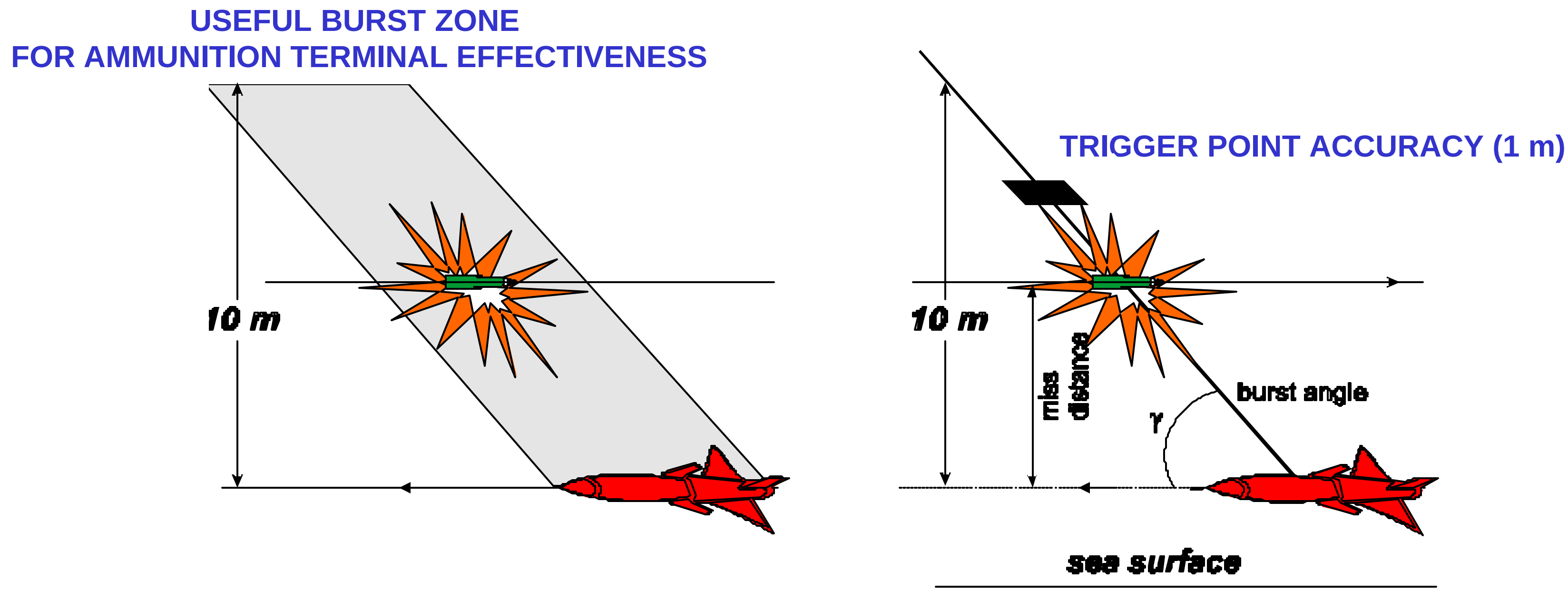
CHARACTERISTICS OF THE NEW MICROWAVE FUZE



- BURST POINT OPTIMIZATION ACCOUNTING FOR MISS DISTANCE AND RELATIVE INTERCEPTION SPEED
- INSENSITIVE TO SEA CLUTTER
- ECM PROTECTION

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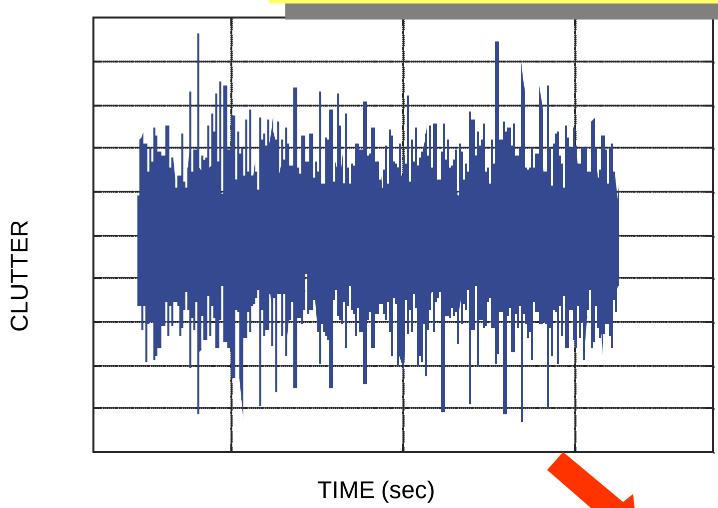
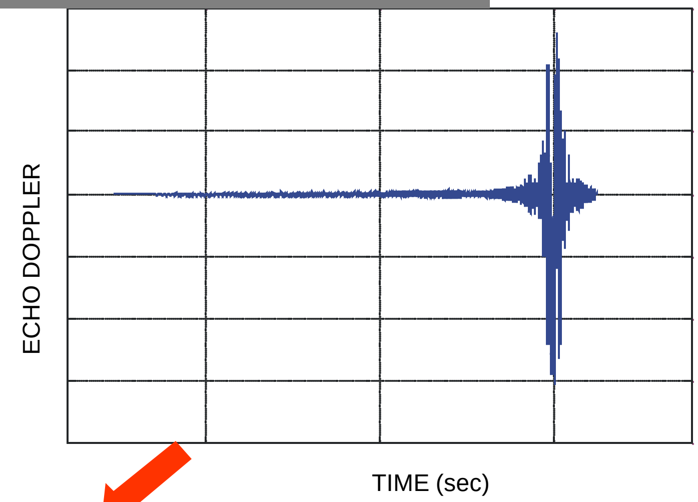
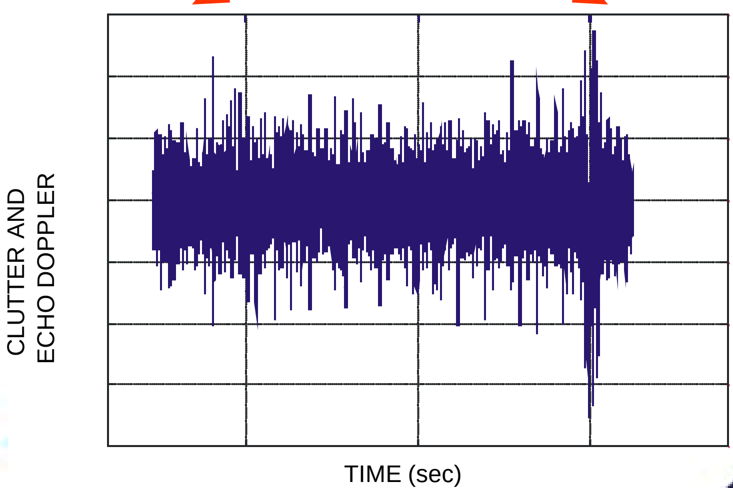
HIGH SENSITIVITY RADIUS

ACHIEVED BY

- LOW NOISE SENSOR
- HIGH COMPUTATION CAPABILITY DIGITAL SIGNAL PROCESSOR
- FFT AND PATTERN MATCHING ALGORITHMS







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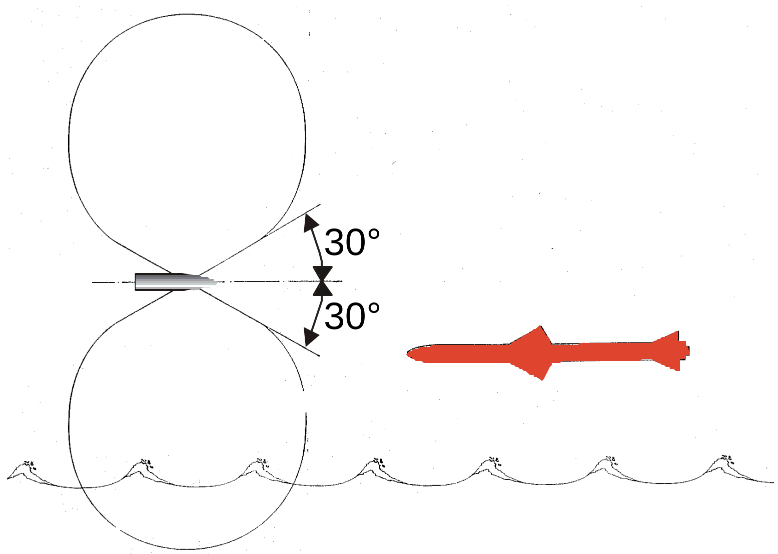
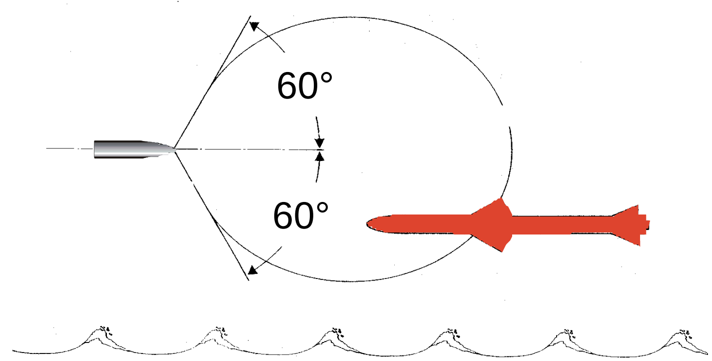
REJECTION OF SEA CLUTTER NOISE AND IMPROVEMENT TO TARGET DETECTION RANGE

BODY ANTENNA FUZE



NEW MICROWAVE FUZE



- INCREASE TARGET DETECTION RANGE
- REDUCE CLUTTER NOISE

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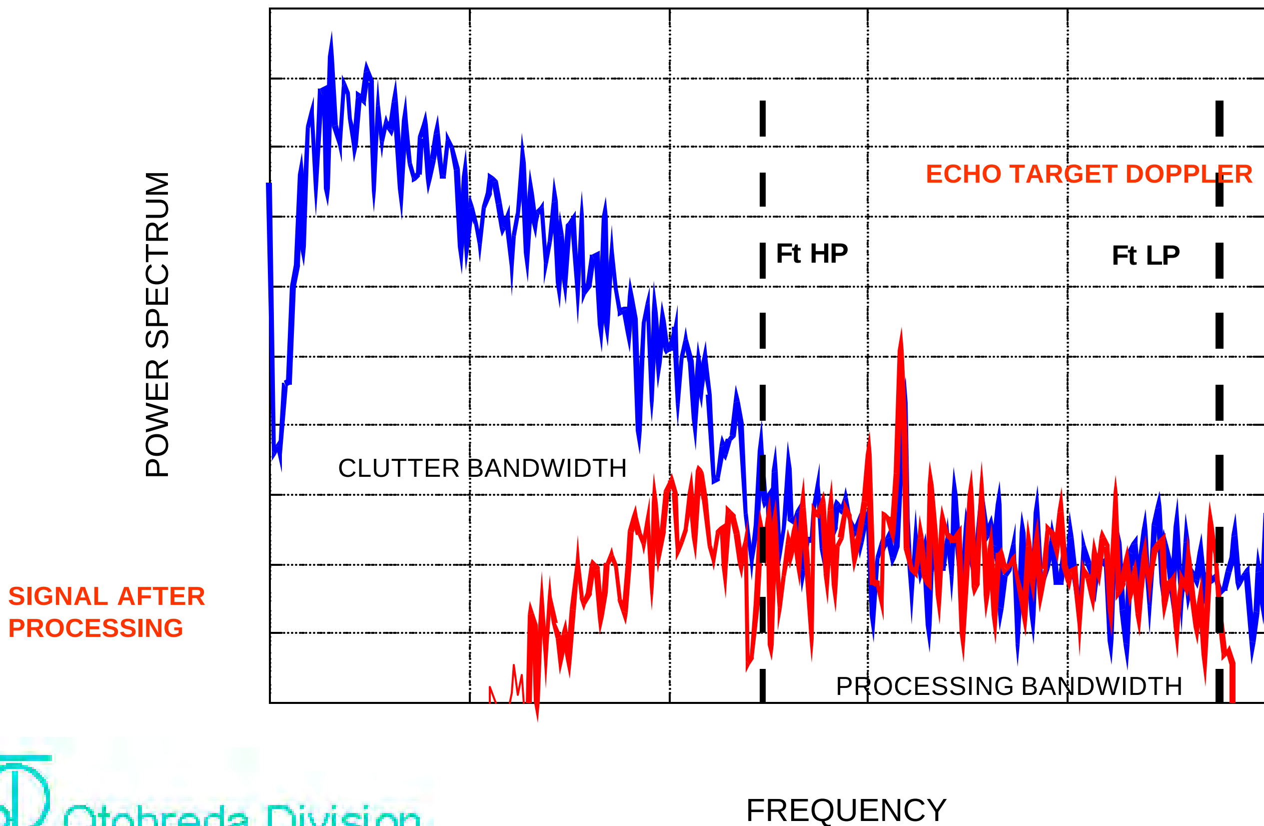
REJECTION OF SEA CLUTTER NOISE

ACHIEVED BY

- **OPERATING NARROW BANDWIDTH ANALYSIS TO SEPARATE TARGET SIGNAL FROM CLUTTER NOISE**
- **INCREASING FUZE RF FREQUENCY TO INCREASE THE TARGET/CLUTTER SEPARATION**



SPECTRUM OF SIGNAL (CLUTTER AND ECHO DOPPLER) RECORDED ABOUT 90 m BEFORE TARGET INTERCEPT

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Microwave Fuze

LOW SENSITIVITY TO EM ENVIROMENT

ACHIEVED BY

- AN ELECTRONIC SETTER MOUNTED ON THE GUN WHICH ENABLES THE FUZE PROXIMITY MODE ONLY IN VICINITY OF TARGET
- USING NARROW BANDWITH SENSOR, ROBUST DIGITAL SIGNAL PROCESSING, ADVANCED SW LOGICS

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PERFORMANCES IN PRIMARY ROLE

Primary Role	: ANTIMISSILE
Radial Sensitivity	: > 10 m
Action Probability	: > 95%
Level on sea	: down to 2 m

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IMPROVEMENTS TO THE "76/62 GUN BASED" SYSTEM

COMPARISON BETWEEN NEW MICROWAVE FUZE AND BODY ANTENNA FUZES (SEA SKIMMING MISSILE)

	MICROWAVE	BODY ANTENNA
RADIAL SENSITIVITY	> 10 m	3 m
TRIGGERING ACCURACY	1 m	2 m
DETONATION POINT OPTIMIZATION	ACCURATE (1)	COARSE
SEA CLUTTER REJECTION	VERY HIGH	MEDIUM
ECM PROTECTION	VERY HIGH	LIMITED

(1) Function of relative speed and miss distance

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FIRING TEST AGAINST LOW ALTITUDE TARGET

TEST LOCATION: BALIPEDIO “COTTRAU”

LA SPEZIA
15 JUNE 2000

8 ROUNDS FIRED WITH MISS DISTANCES BETWEEN 3 AND 6 m

MOVIE SHOWING 8 FIRINGS

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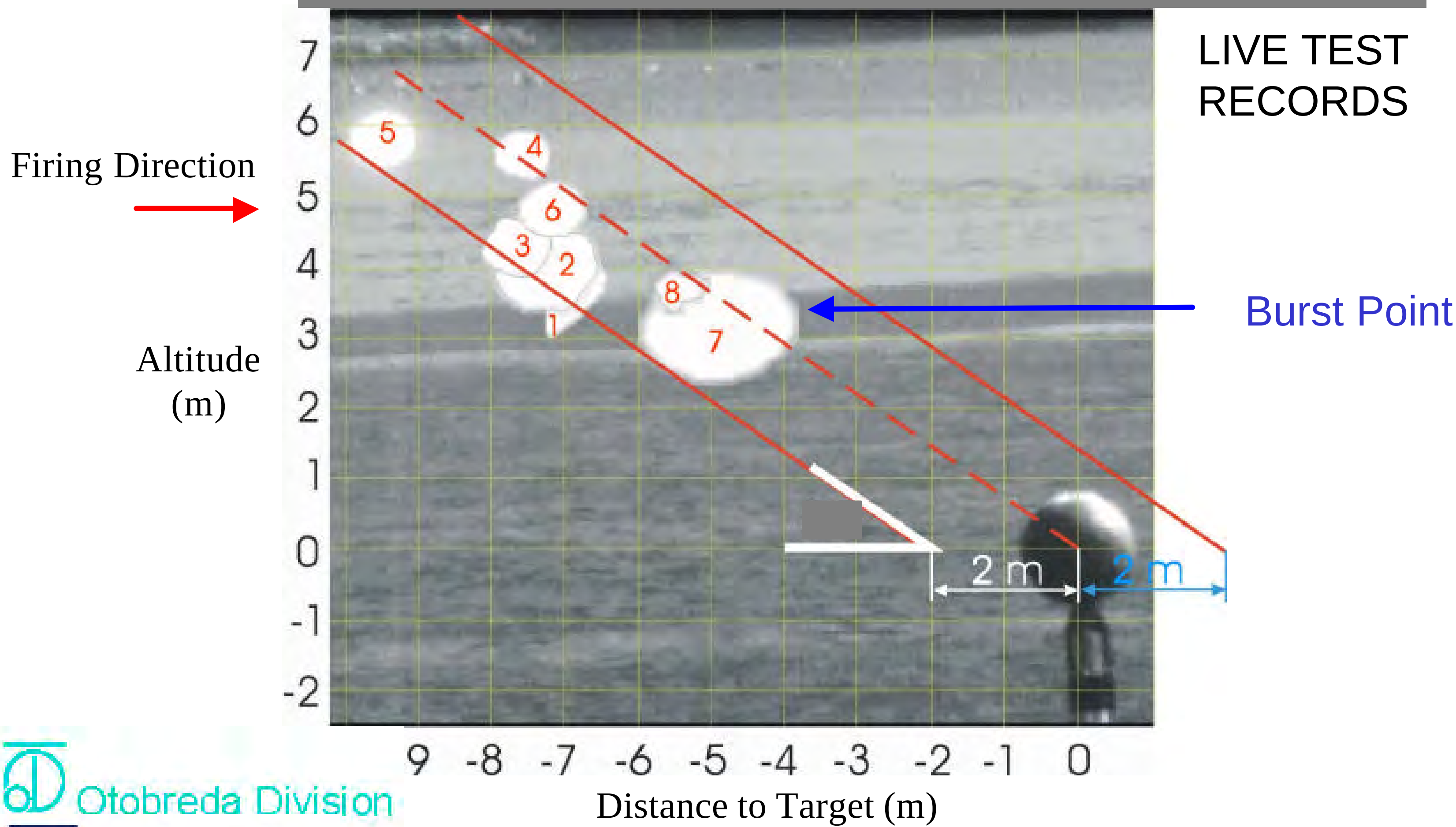
ACCURACY OF BURST POINT

ACHIEVED BY

- HIGH SPEED COMPUTATION FOR SIGNAL FREQUENCY ANALYSIS
- TRIGGER DECISION MADE BY ADVANCED SIGNAL PROCESSING INSTEAD OF TIME/AMPLITUDE ANALOG PROCESSING



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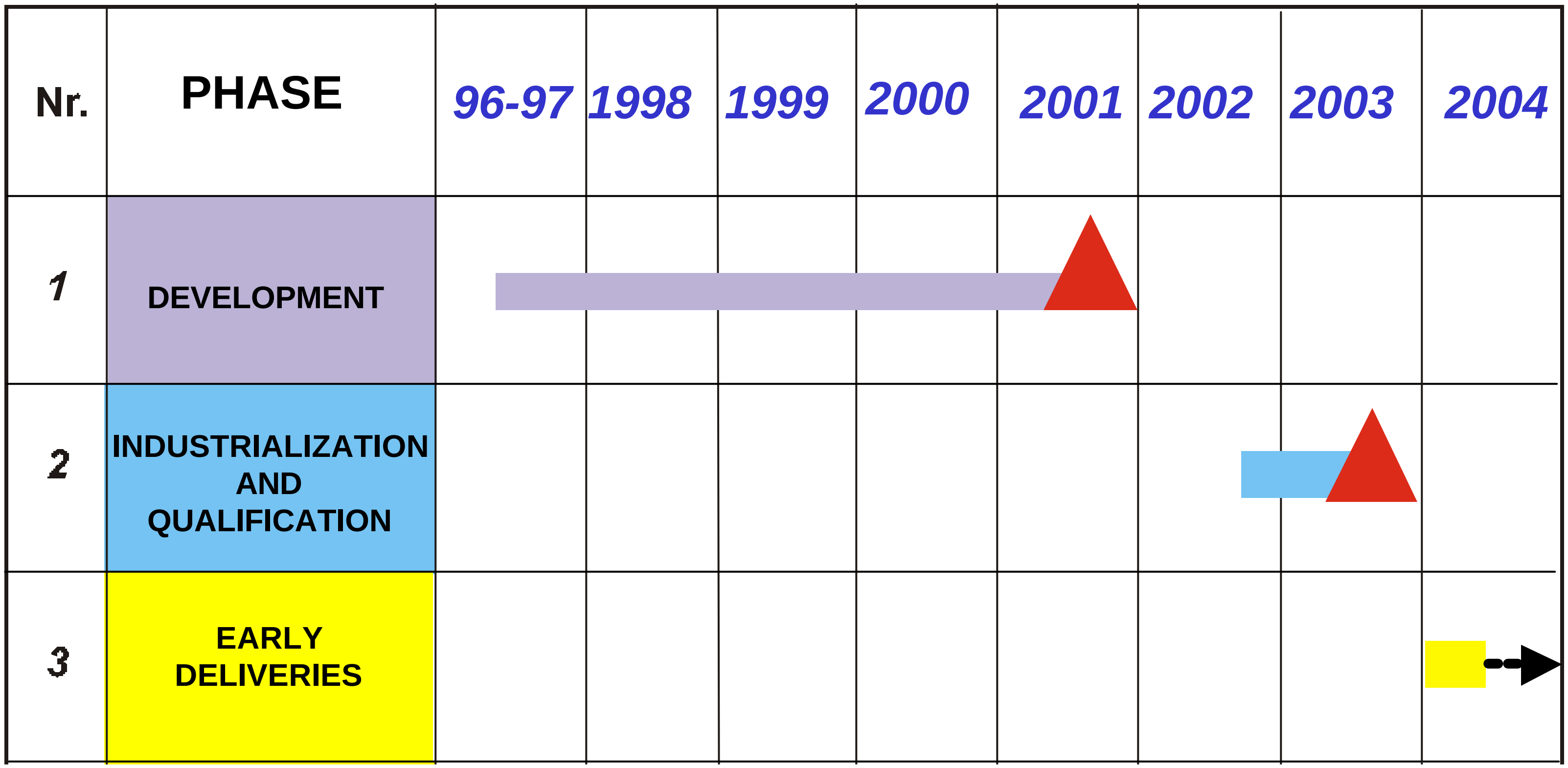
Microwave Fuze

DEVELOPMENT PROGRAM AND INDUSTRIALIZATION



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JUNGHANS
Feinwerktechnik

Optronic
Mortar Proximity Fuze
PX581

Presentation for 45th Annual Fuze Conference
April 17, 2001
Long Beach, CA

by Peter Becker*, Dr. Gerhard Nowicki,
Dr. Ulrich Obbarius, Frank Kienzler

Cooperation
Noptel – JUNGHANS

noptel

JUNGHANS
Feinwerktechnik

Basis of the cooperation NF2000M

noptel

JUNGHANS
Feinwerktechnik

Reason for the cooperation

Adjoining the technical specialities of JUNGHANS and Noptel

noptel

- Optronic distance measurement

JUNGHANS
Feinwerktechnik

- Fuze design
- Safety concept
- Mechanics
- Fuze assembly

Product Program

- Fuzes for Medium Caliber Ammunition
- Mortar Fuzes
- Fuzes for Tank Gun Ammunition
- Fuzes for Rockets and Missiles
- Artillery Fuzes
- Fuzes for AT-Weapon Ammunition
- Safety and Arming Devices
- Miscellaneous Products

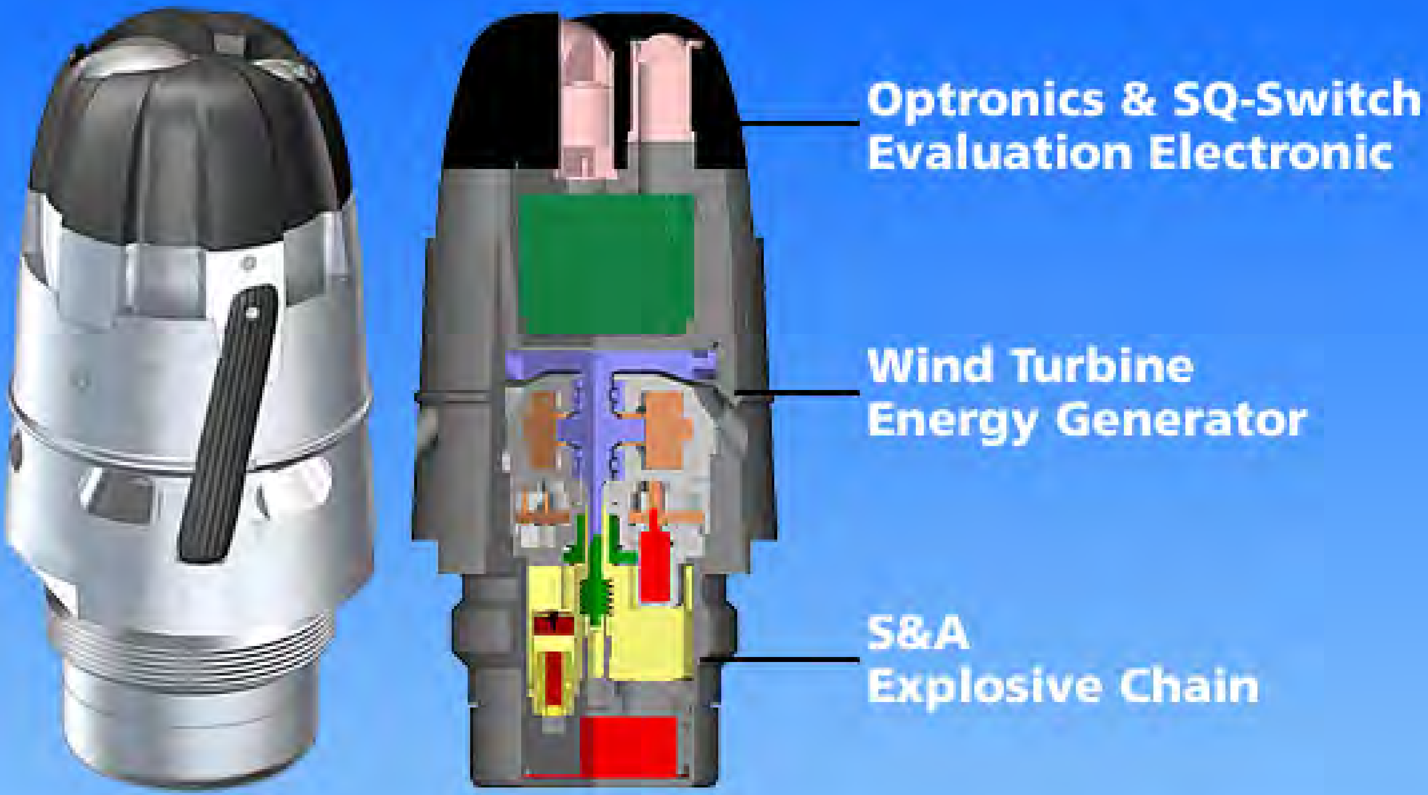
Mortar Fuzes

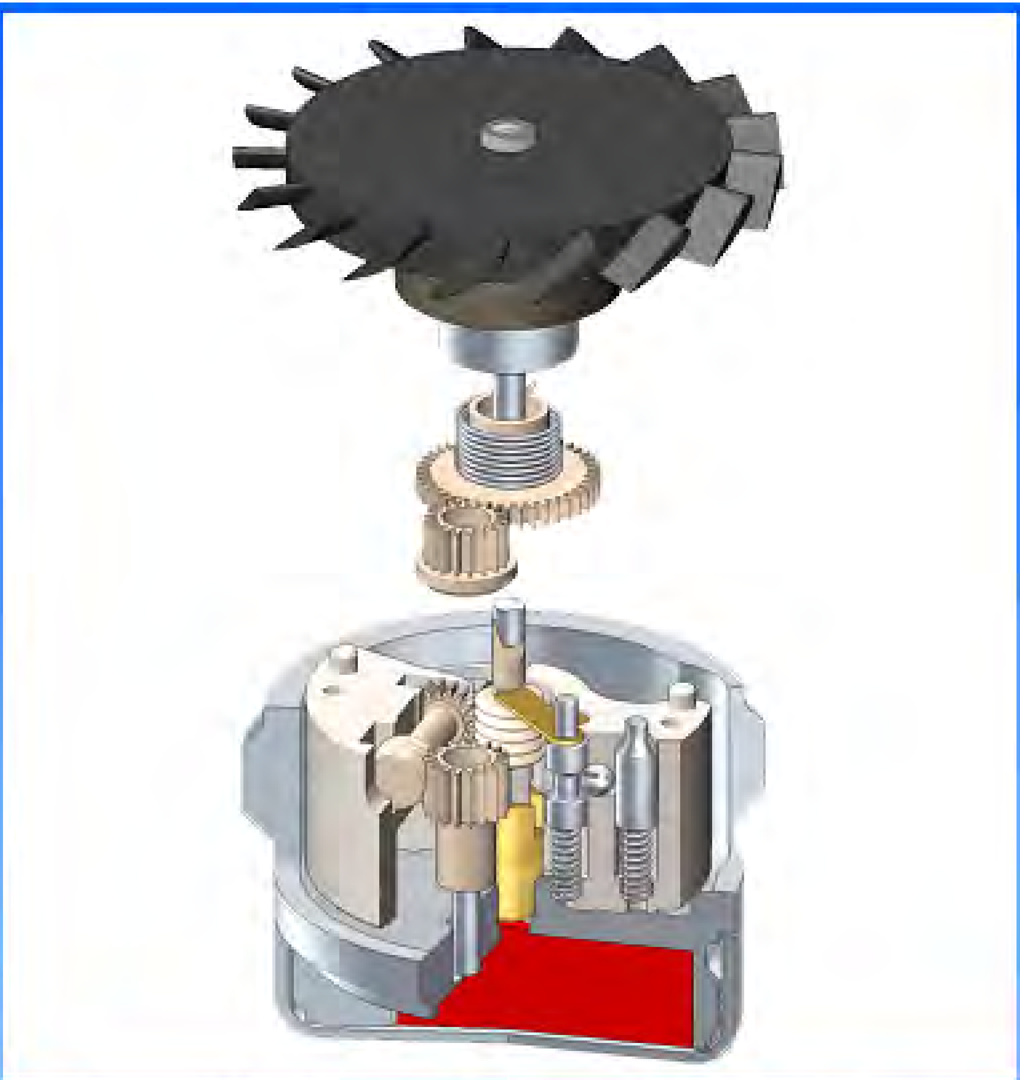
DM93 / M776	MTSQ Fuze
M772	MTSQ Fuze
DM111A4	PD Fuze
DM111A5	PD Fuze
PX581	PROX Fuze

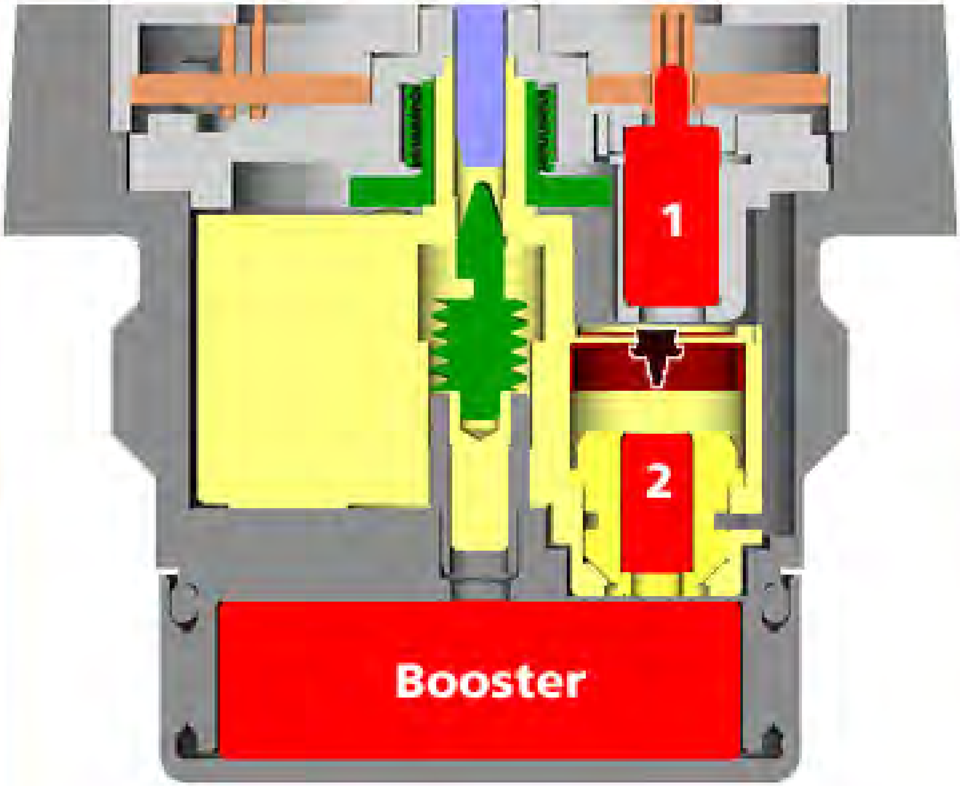
PX581 Optronic Proximity Fuze

- PROX (backup SQ and delay)
- 60, 81, 120 mm HE, SMK bombs
- Preset height 1, 2, 3, 4 or 5 m
- MIL STD 1316D
- Muzzle safety distance ≥ 100m
- Trajectory safety: APEX
- ≥ 98% reliability (95% prob.)
- –40°C (–46°C) to +63°C

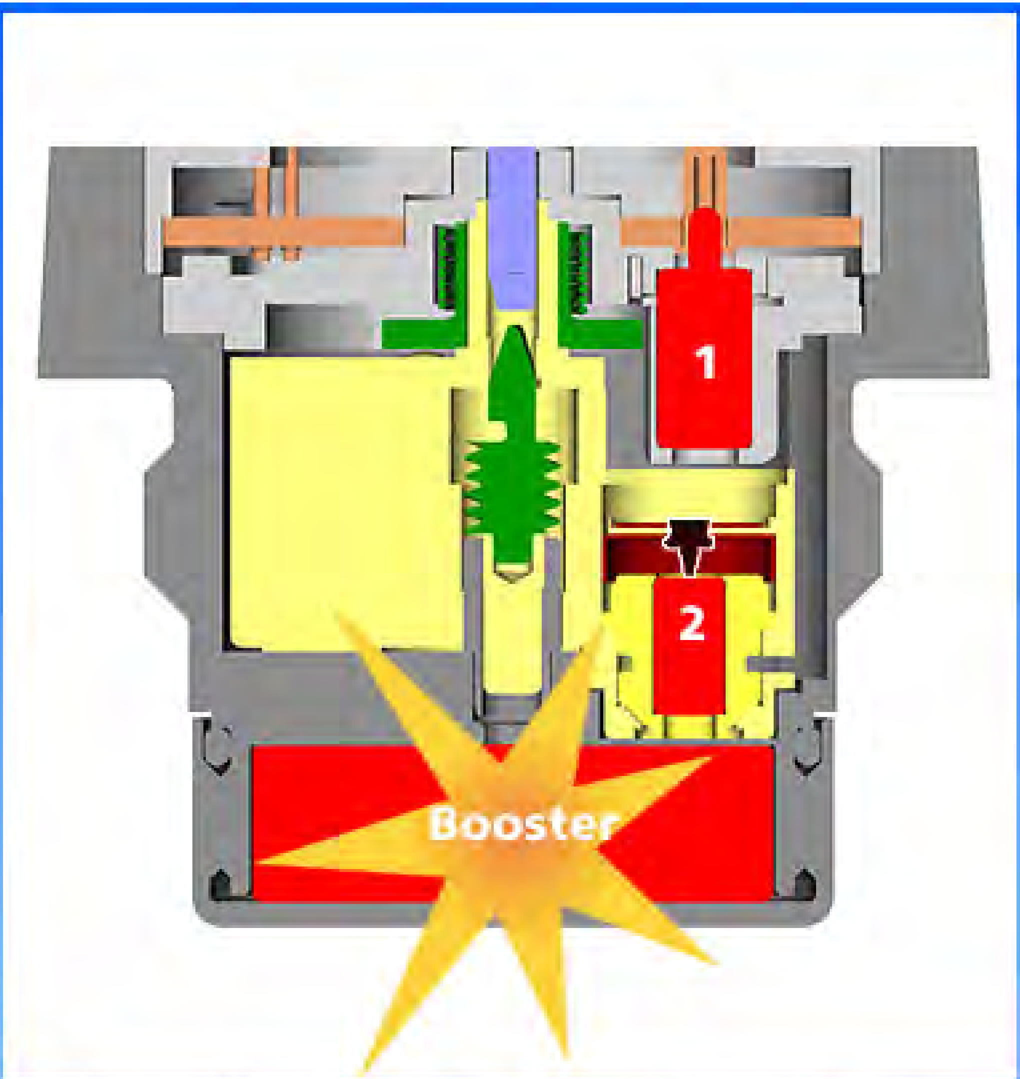
PX581 Optronic Proximity Fuze

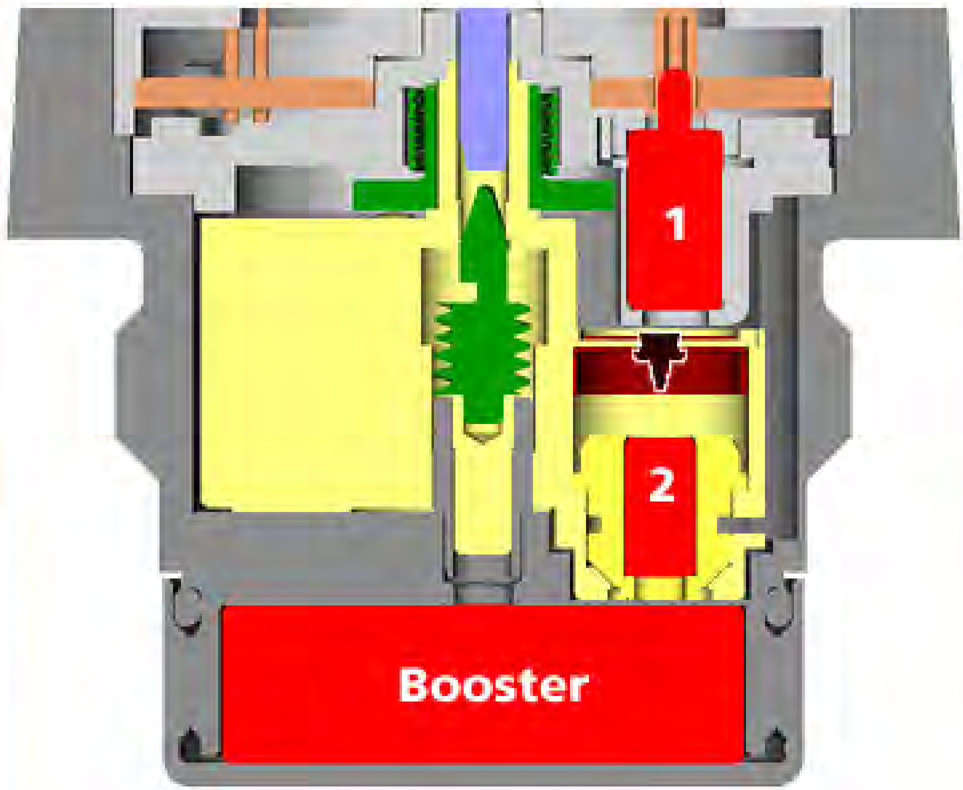




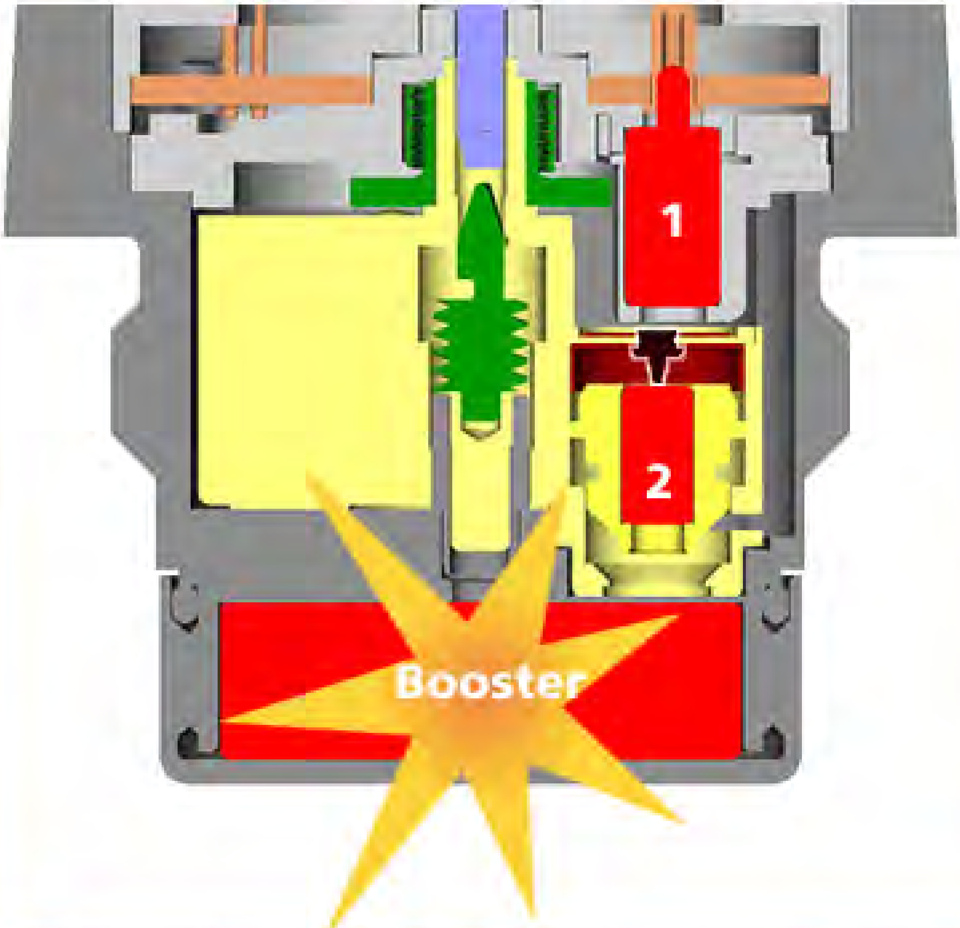


S&A
Proximity
PD
Product Program
Product Group
Product
Components
Animation
Status
Trajectory


1
2
Booster


1
2
Booster

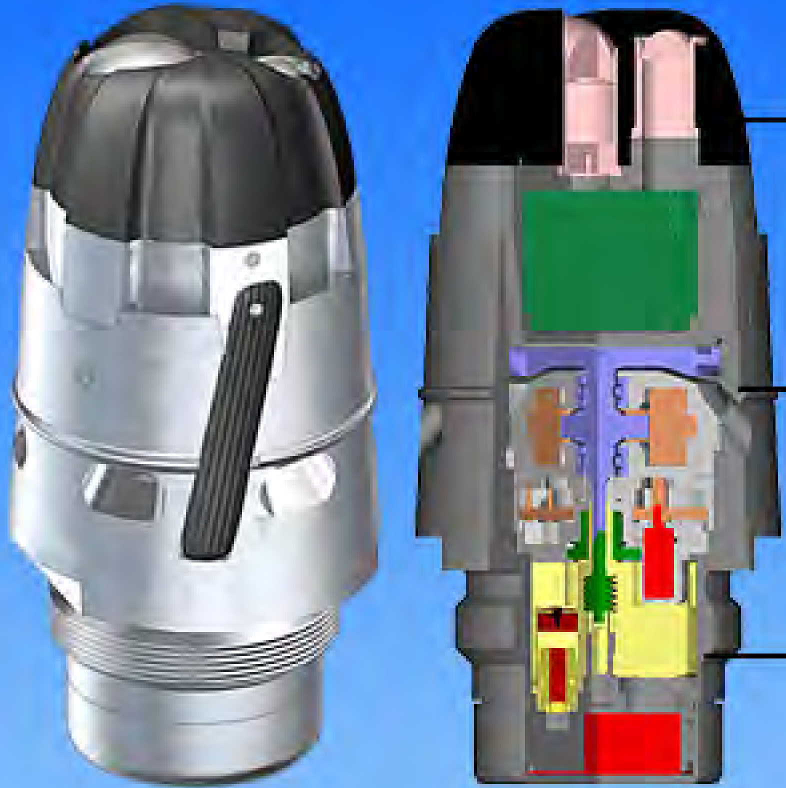
IMPACT!



S&A
Proximity
PD

Product Program | Product Group | Product | Components | Animation
Status | Trajectory

PX581 Optronic Proximity Fuze



PX581 Optronic Proximity Fuze

- Optronics & SQ-switch Evaluation electronic

Preset heights ex works

1, 2, 3, 4, or 5 meters ± 1 meter

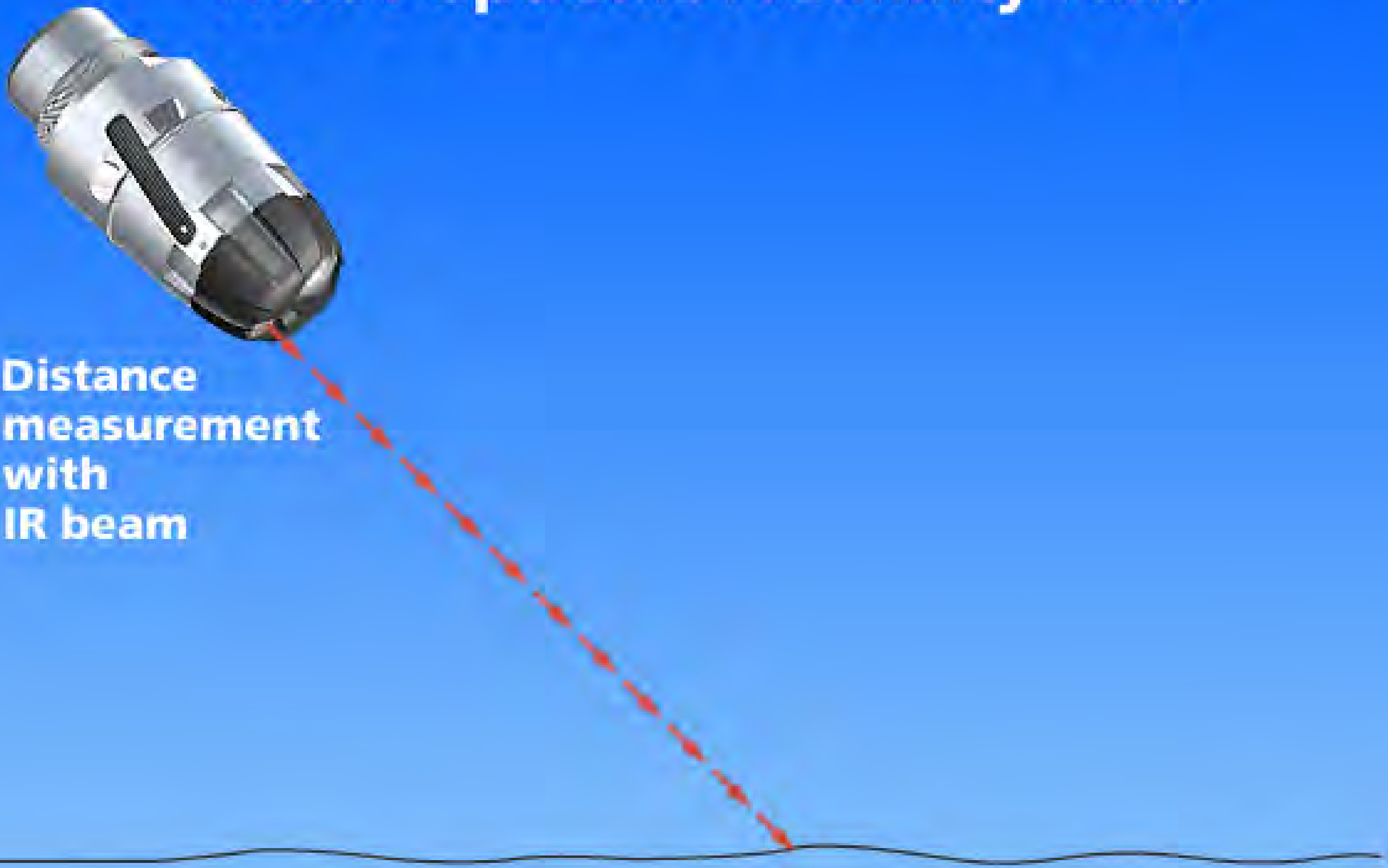
PX581 Optronic Proximity Fuze

- Optronics & SQ-switch Evaluation electronic

Preset heights ex works

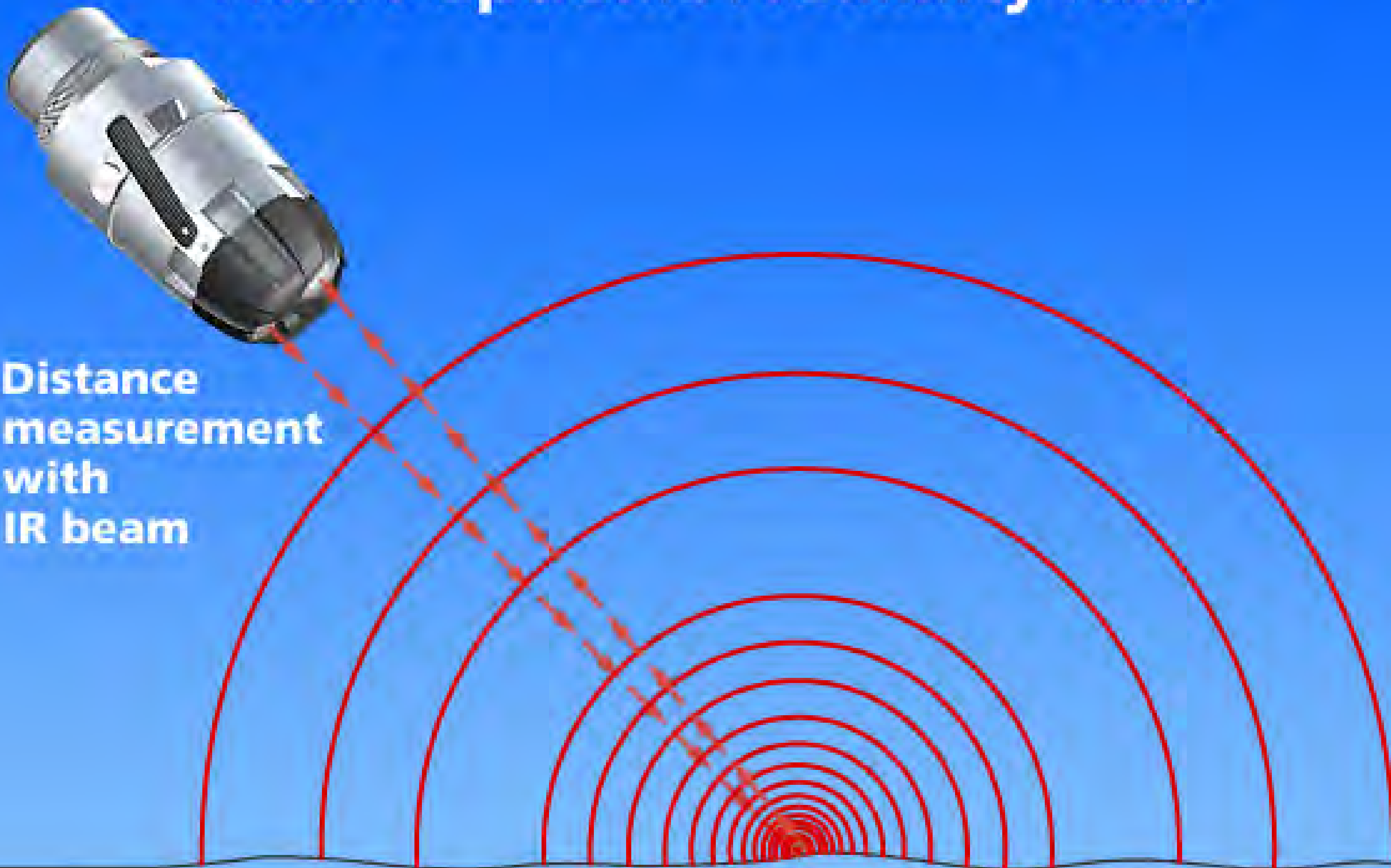
1, 2, 3, 4, or 5 meters ± 1 meter

PX581 Optronic Proximity Fuze



- **Distance measurement with IR beam**

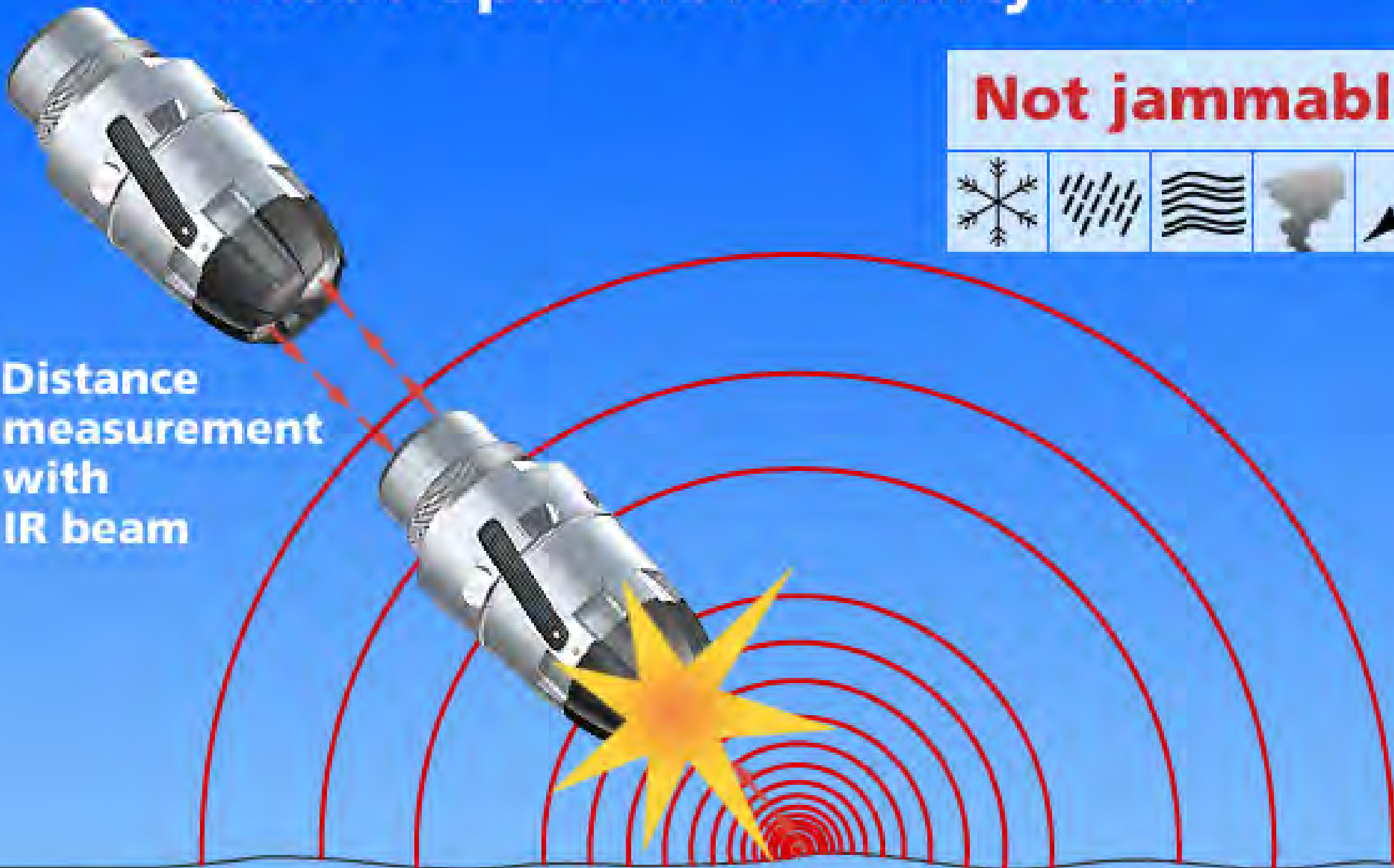
PX581 Optronic Proximity Fuze



- Distance measurement with IR beam

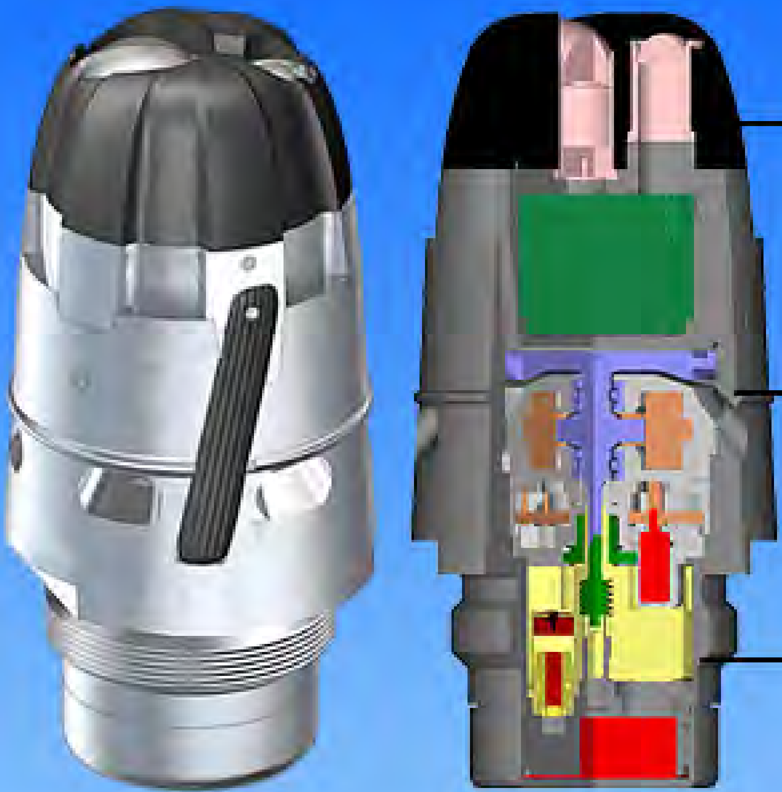
PX581 Optronic Proximity Fuze

Not jammable



- **Distance measurement with IR beam**

PX581 Optronic Proximity Fuze



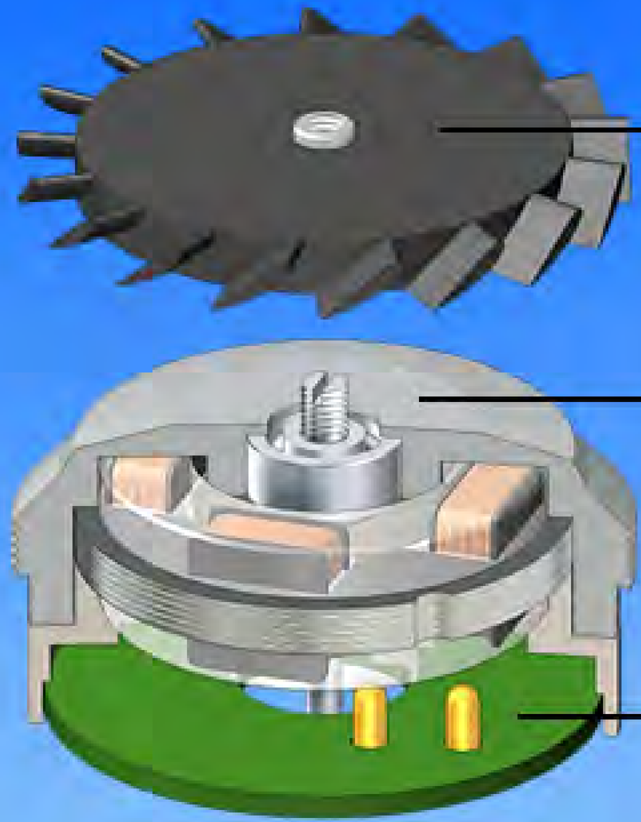
Optronics & SQ-Switch
Evaluation Electronic

Wind Turbine
Energy Generator

S&A
Explosive Chain

PX581 Optronic Proximity Fuze

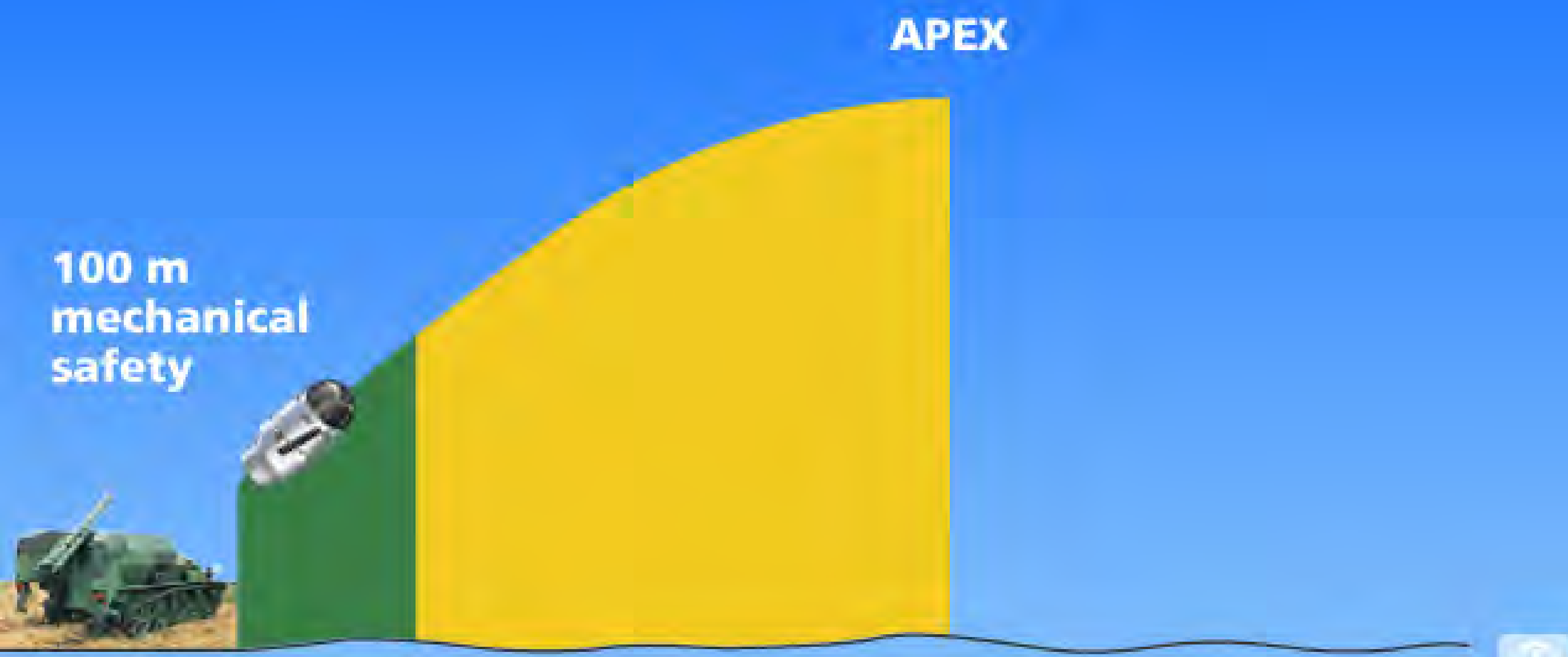
- **Wind turbine**
  Energy generator



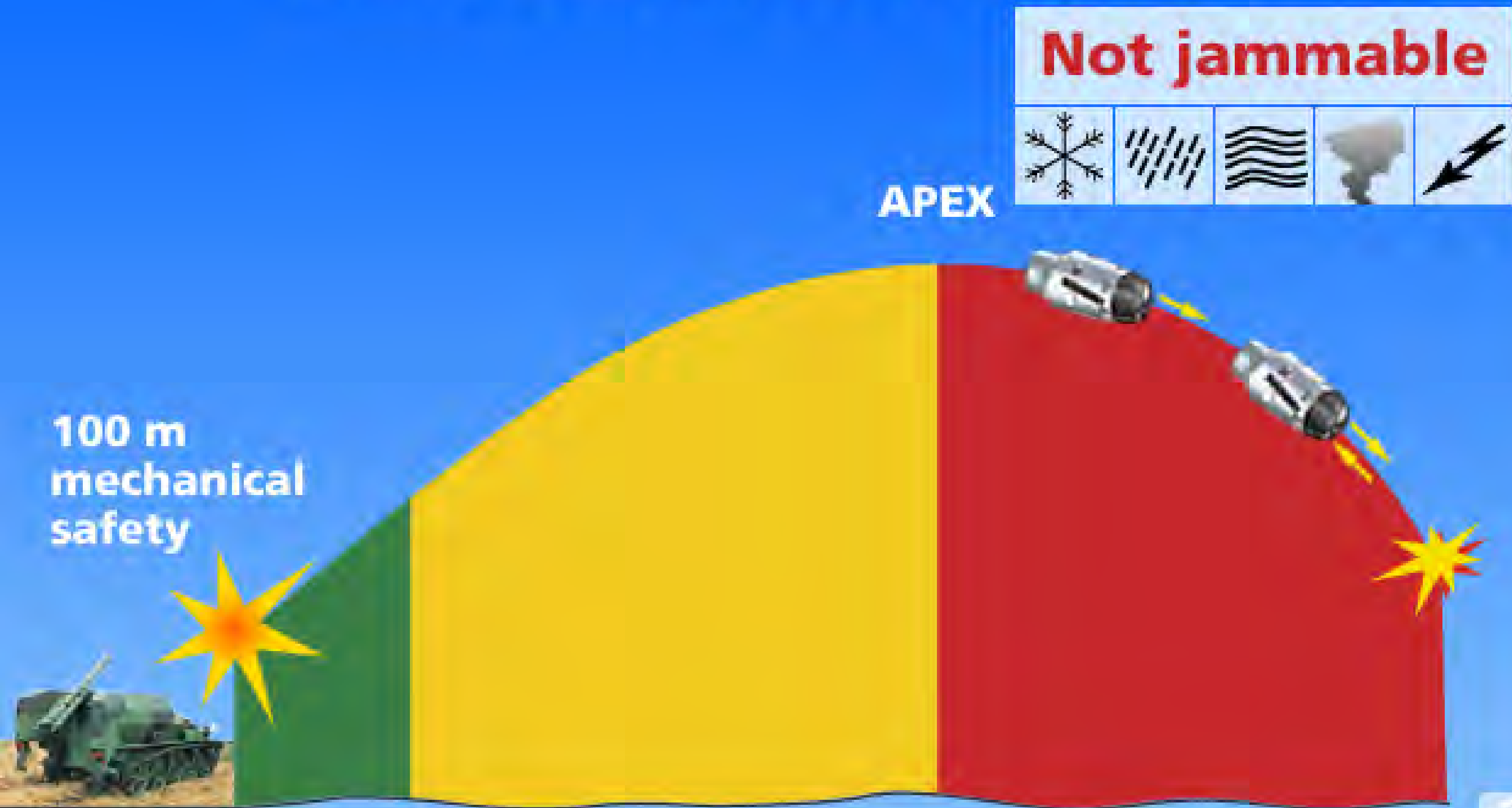
PX581 Optronic Proximity Fuze

100 m mechanical safety

PX581 Optronic Proximity Fuze



PX581 Optronic Proximity Fuze



PX581 Optronic Proximity Fuze

Status

- **Development**
  various subassembly and firing tests: until 06/2001
- **Company qualification: 10/2001**
- **Start of series production: 04/2002**

Conclusion

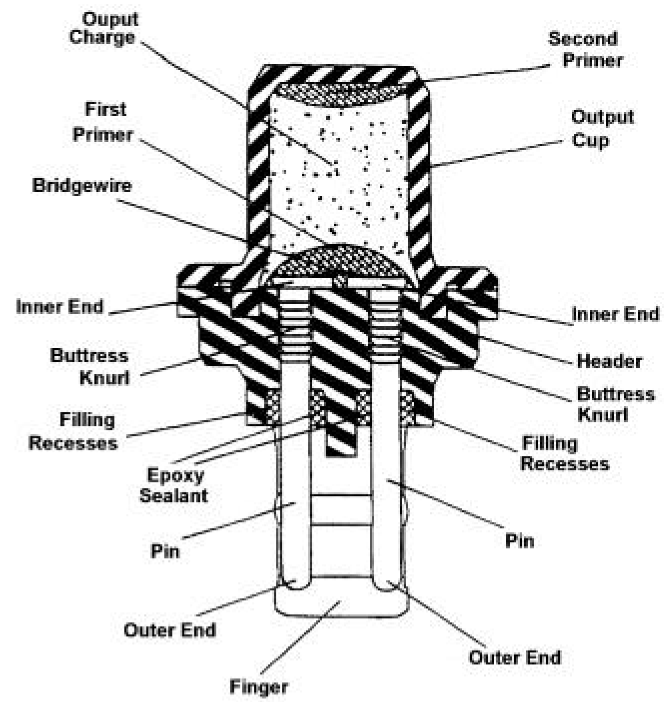
- Most modern fuze design
- Usable with
  60 / 81 / 120 mm Ammo
- Highly precise distance measurement
- Not jammable
- No stored energy
- Two independent safety criteria
- In production from 2002 on

The Reactive Bridge: A Novel Solid-State Low Energy Initiator

Dr. Thomas A. Baginski (Auburn University)
David Fahey (Quantic Industries)

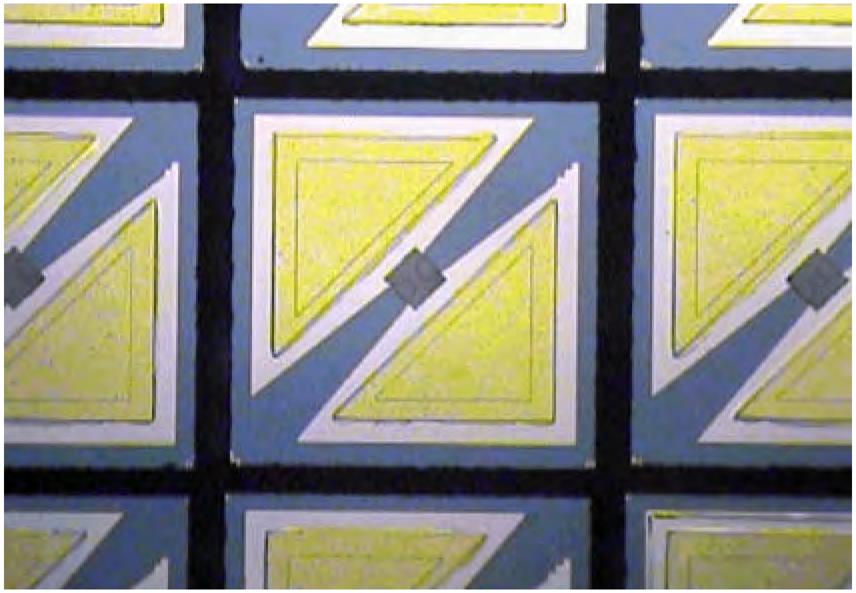
EED Structure

- Conductive Pins
- Header and Cup
- Bridgewire
- Primary Charge
- Output Charge



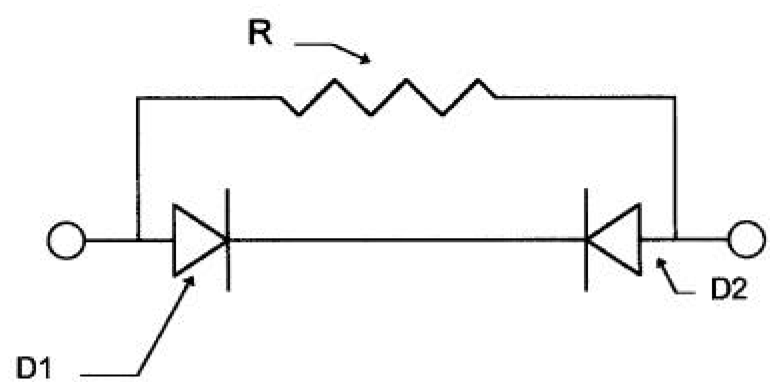
Reactive Bridge vrs. Bridgewire

- Faster Actuation (<5μsec)
- Lower Firing Energy (<30μJ)
- Smaller Dimensions (Feature size <20μms)
- Reliable Ignition Across Airgap
- Insensitive to ESD
- Fabricated with Conventional Microelectronic Processes



Design Model

- Resistive Heating Element (1Ω -10Ω)
- Two PN Junction Diodes in Parallel for ESD Protection (Breakdown Voltage ~4V ⇔20V)

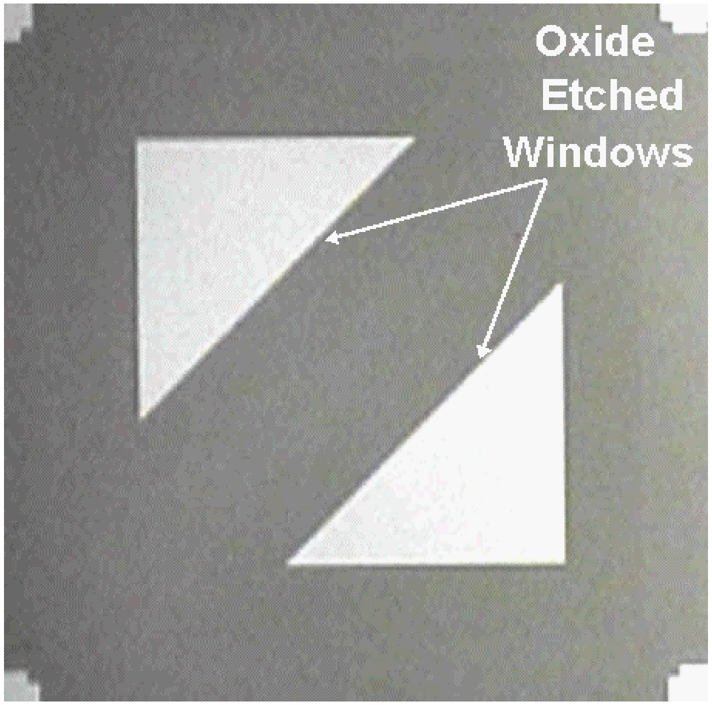


Composite Reactive Bridge Fabrication

- Utilizes Basic Fabrication Techniques
- Photolithography
- Wet Chemical Etching
- Sputtering and E-beam Metal Deposition
- Liftoff Process

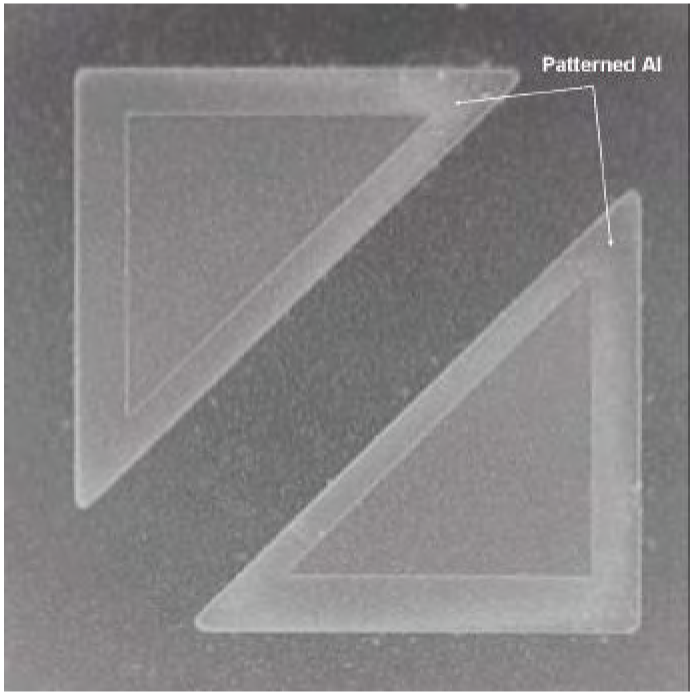
Implant and Diffusion

- Etch Oxide Window using BOE
- Typical Ion Implant
  - B
  - $Q = 5E15/cm^2$
  - Energy = 50keV
- Typical Drive-In
  - 1000°C, N_2
  - 15 minutes



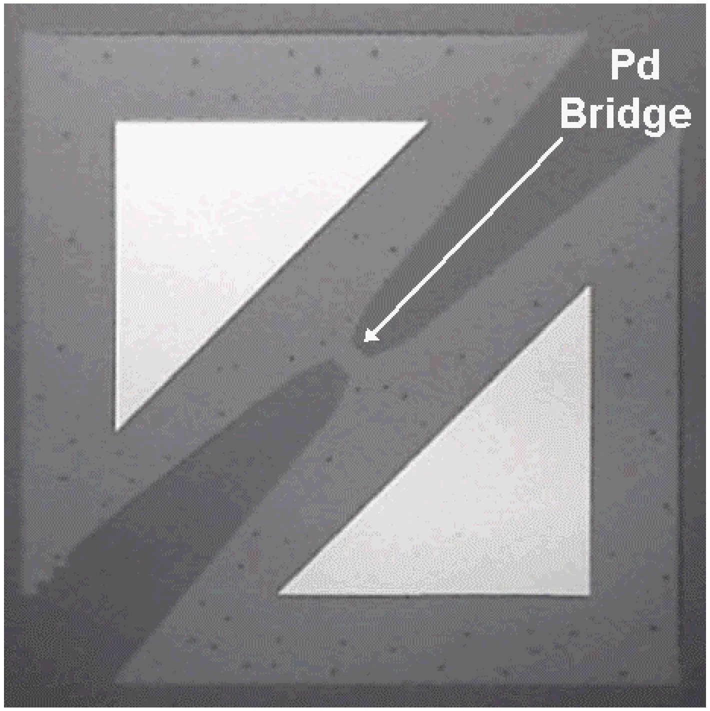
Aluminum Deposition

- Sputter ~12,000Å of Si/Al
- Mask off Window
- Etch Al with PAE
- Etch Residual Si
- Alloy Al at 450°C for 30 minutes



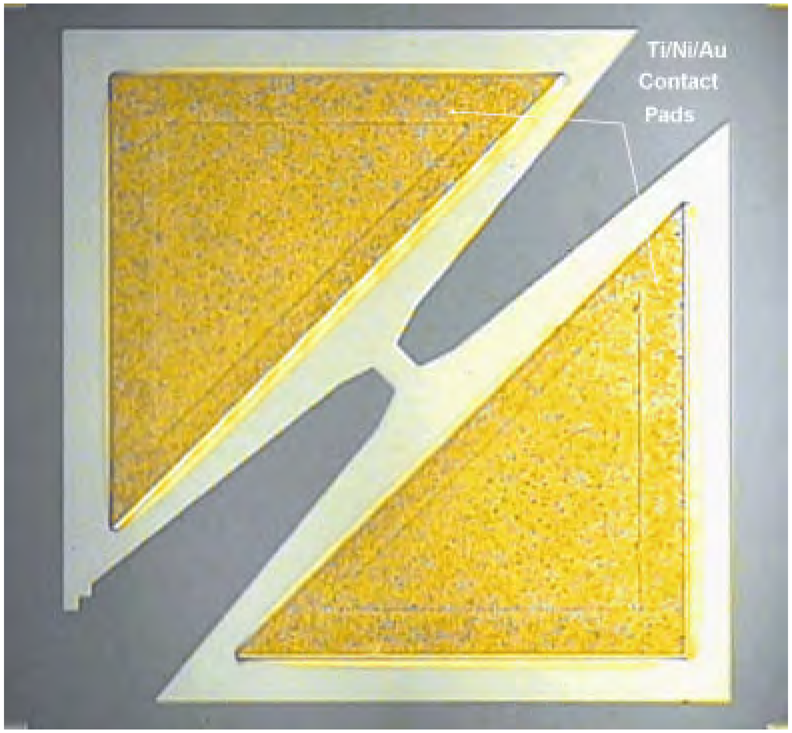
Palladium Deposition

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 2000Å of Pd
- Liftoff
  - Ultrasonic and Acetone



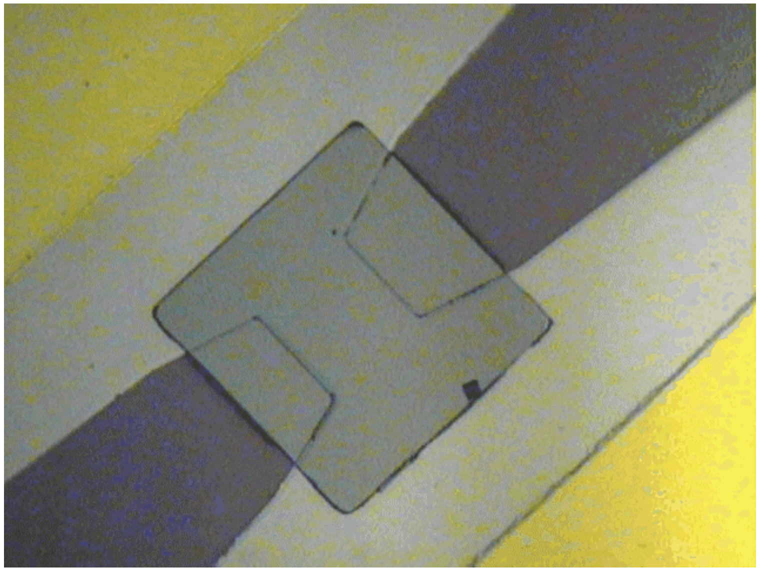
Gold Deposition

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 1000Å of Ni
  - 2000Å of Au
- Liftoff
  - Ultrasonic and Acetone



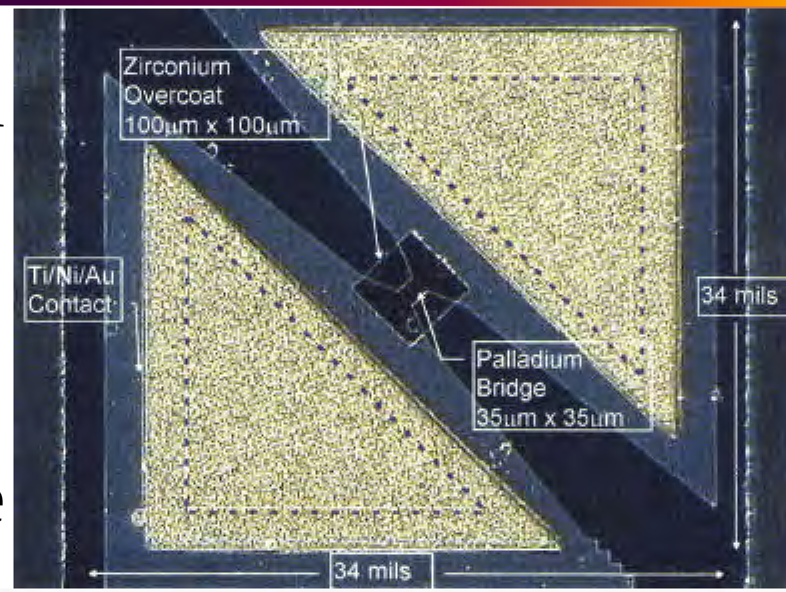
Zirconium Deposition/Reactive Overcoat

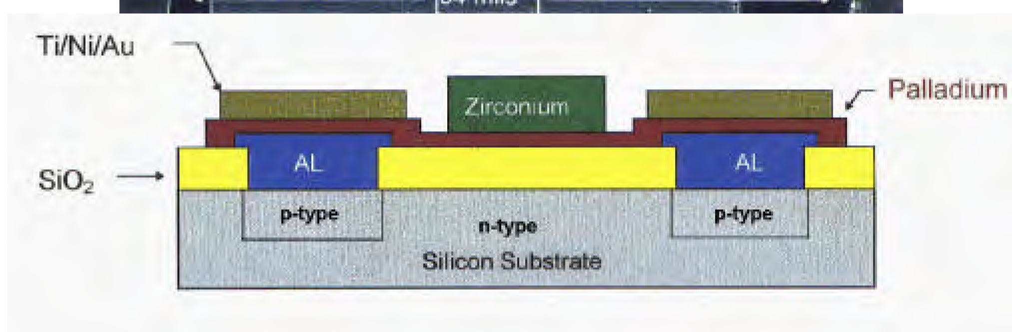
- Mask and Develop
- Deposit
  - 500Å of Ti
  - 10,000Å of Zr
- Additional Mass for Plasma Formation
- Chemically Reactive
- Liftoff
  - Ultrasonic and Acetone



Typical Dimensions

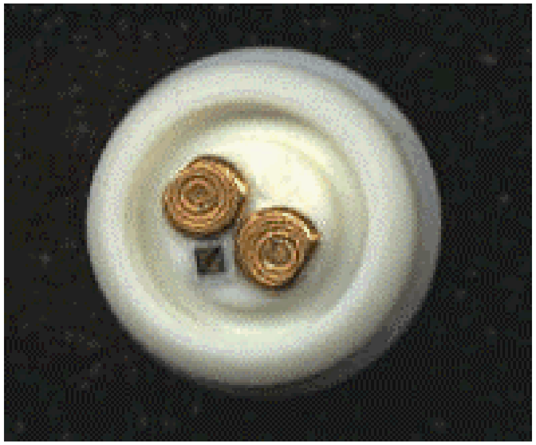
- ~1mm x 1mm, overall size
- 15µm^2 - 40 µm^2 , varying bridge size
- 100µm^2, overcoat size





Packaging

- ValoxDR48 Plastic Header
- Conducting Pins
- Output Cup

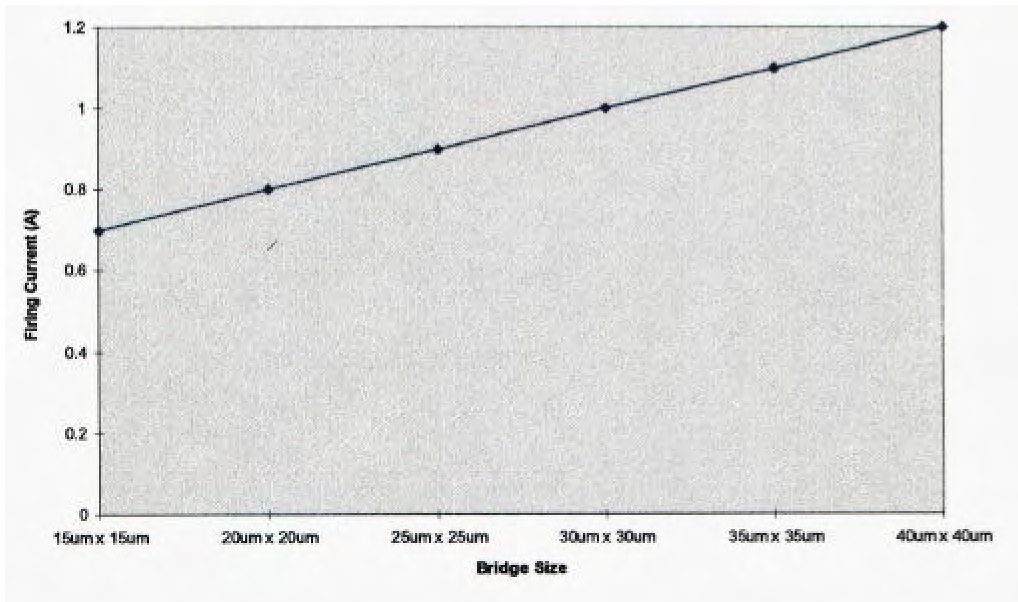


Design Validation Testing

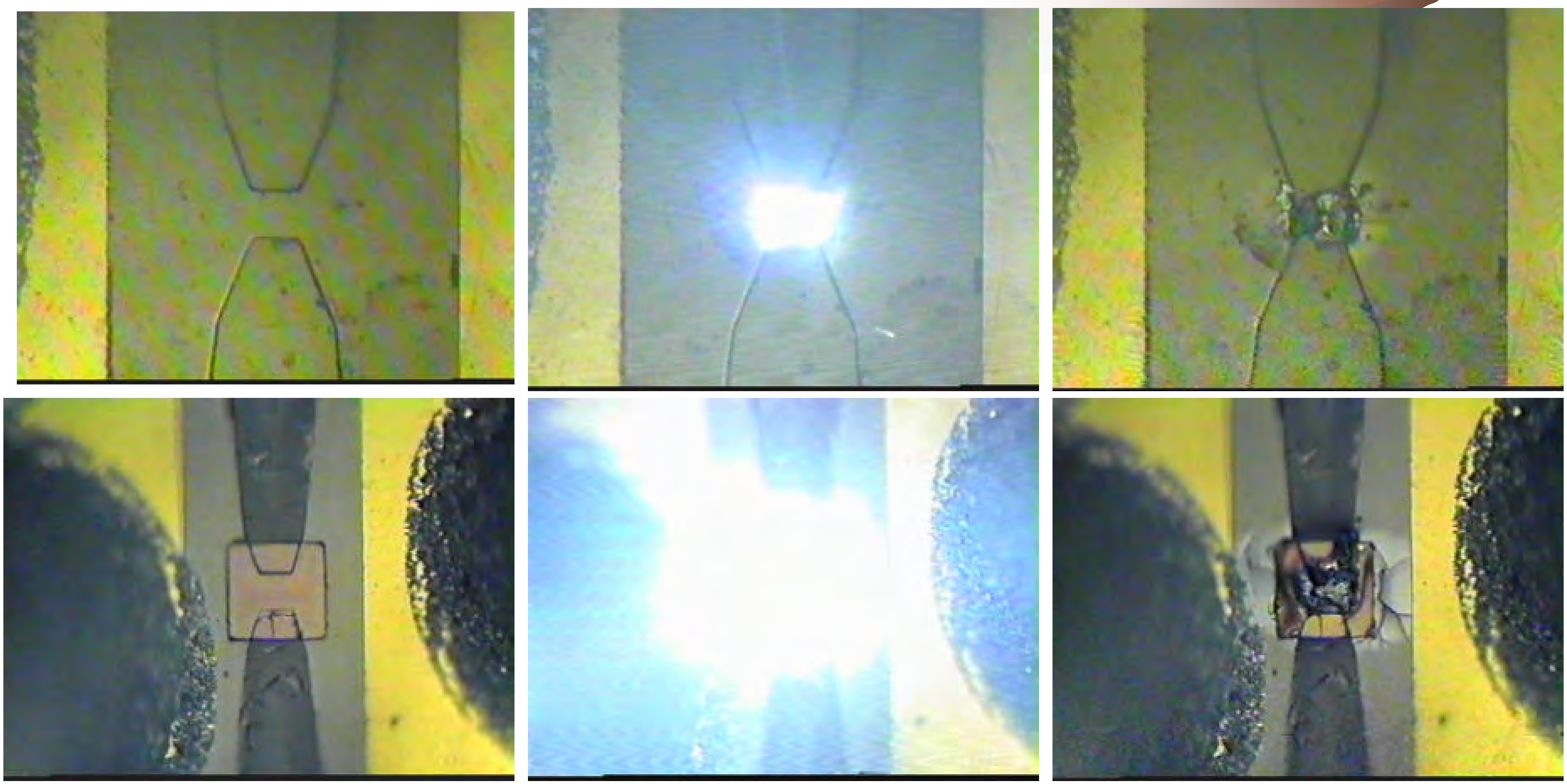
- Firing Current Proportional to Bridge Size
- Firing Energy,

$$Q = \int_0^t (I^2 R)\,dt$$

  - I = Firing Current
  - R = 2Ω (bridge)
  - t = .1msec

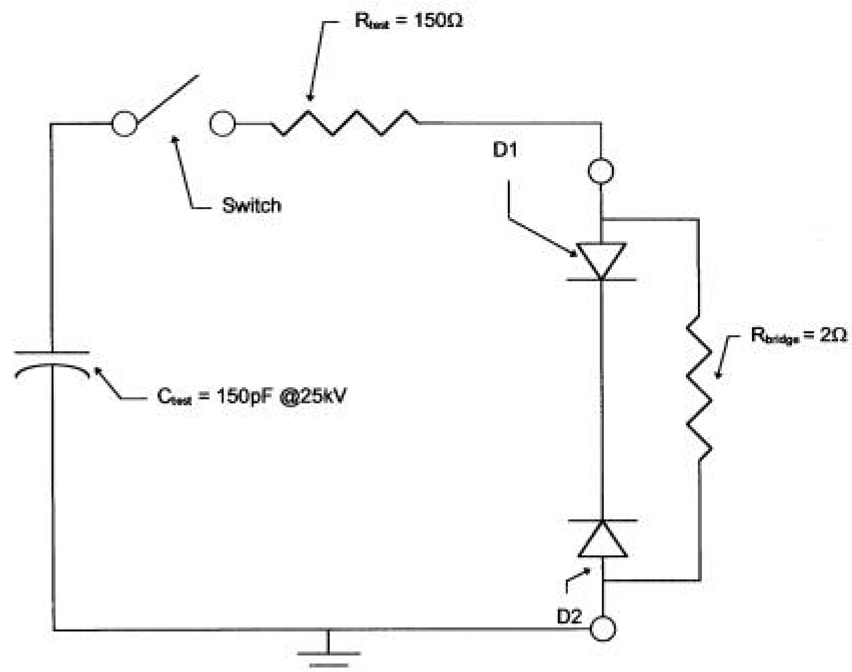


Firing Results With /Without Overcoat 2mF@30V



ESD Test Setup

- 150pF Capacitor Charged to 25kV
- Series Resistor of 150Ω
- Close Switch
- Repeat 5 times



Environmental Test Setup

- 320 Parts
- High Temp, 144 hrs @ 107°C
- Thermal Shock and Humidity
  - 6 cycles(-40°C and 107°C) for 12 hrs
- RandomVibration
  - Method S14:4 category I
  - 3 perpendicular axis, -40°C, 21°C, and 90°C

All Fire/No Fire Data

All Fire / No Fire Summary

Group	Bond	AF @ 1ms, 99.999% @ 95% Confidence -40C	AF @ 1ms, 99.999% @ 95% Confidence +21C	NF @ 10s, 99.999% @ 95% Confidence +90C	NF @ 10s, 99.999% @ 95% Confidence +21C
Baseline	Wirebond	1.037A	NA	.583A	NA
Post Serial Environ.	Wirebond	1.039A	NA	.617A	NA
Baseline	Conductive Epoxy	1.026A	NA	.613A	NA
Post Serial Environ.	Conductive Epoxy	1.040A	0.997A	.613A	.605A

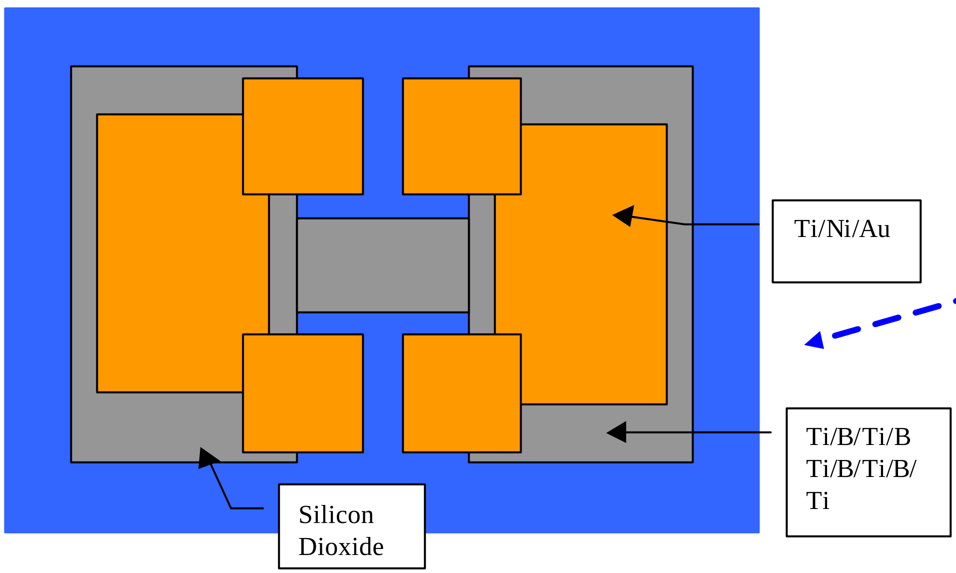
Validation Testing Results

- Results Extremely Positive
- 1.2A, 1msec all-fire
- 0.5A, 10s no-fire
- 99.999% reliability, 95% confidence
- Time to Peak Pressure, < 1ms

The Laminated Reactive Bridge

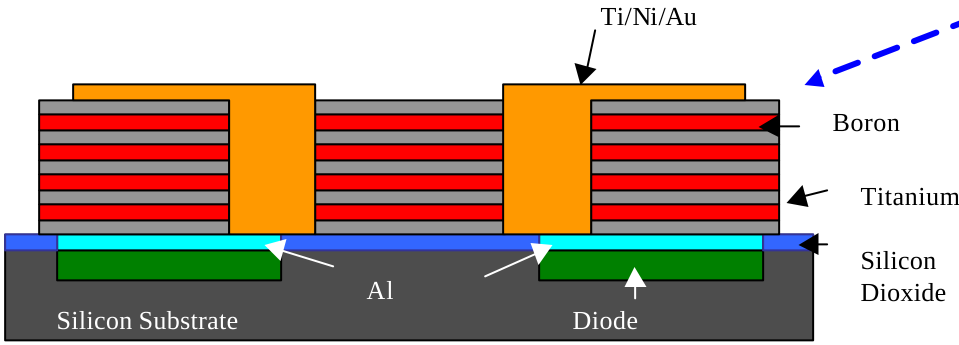
- Structure employs laminations of B/Ti
- Exothermic inter-metallic alloy
- No oxidizer required
- $2B + Ti \Rightarrow 1320 cal/gm$

Laminated Reactive Bridge

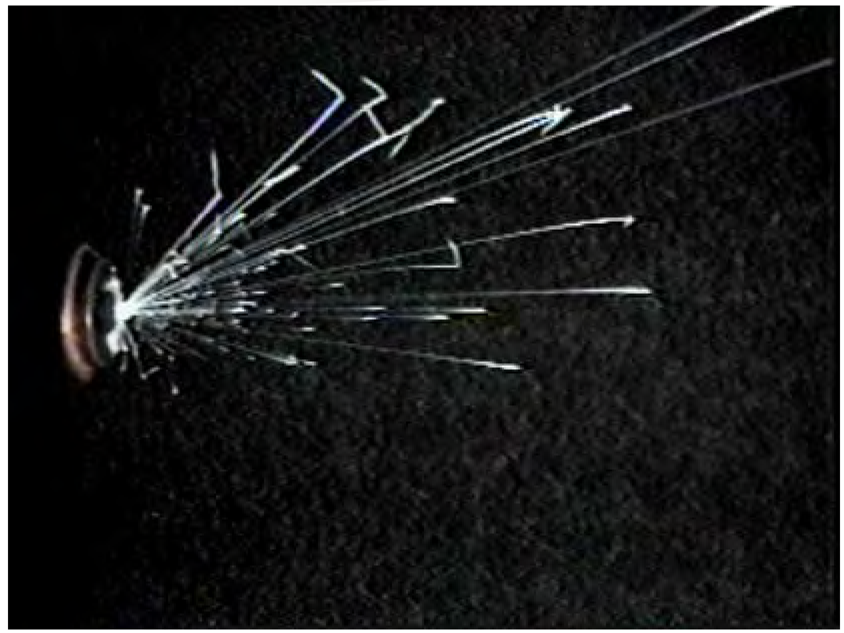


Topview

Sideview



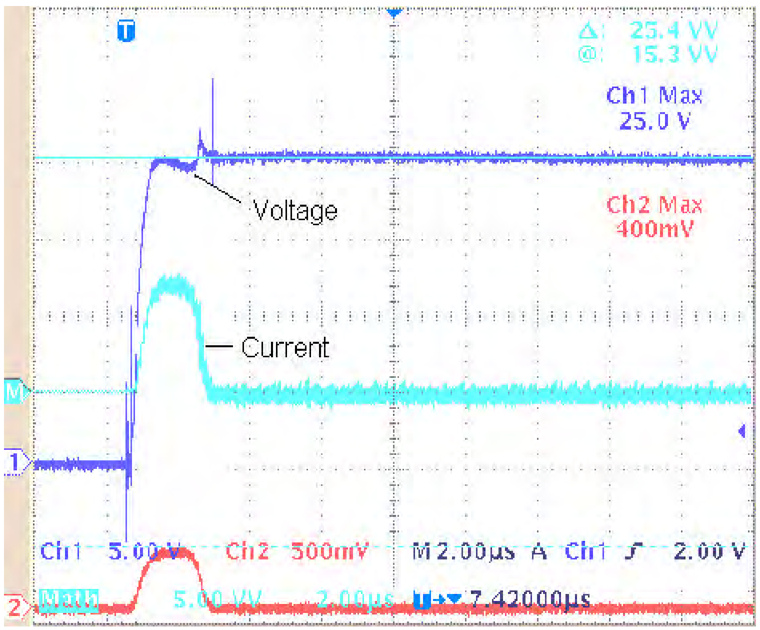
Sample Firing Of Laminated 110mm Bridge 35mF@30V



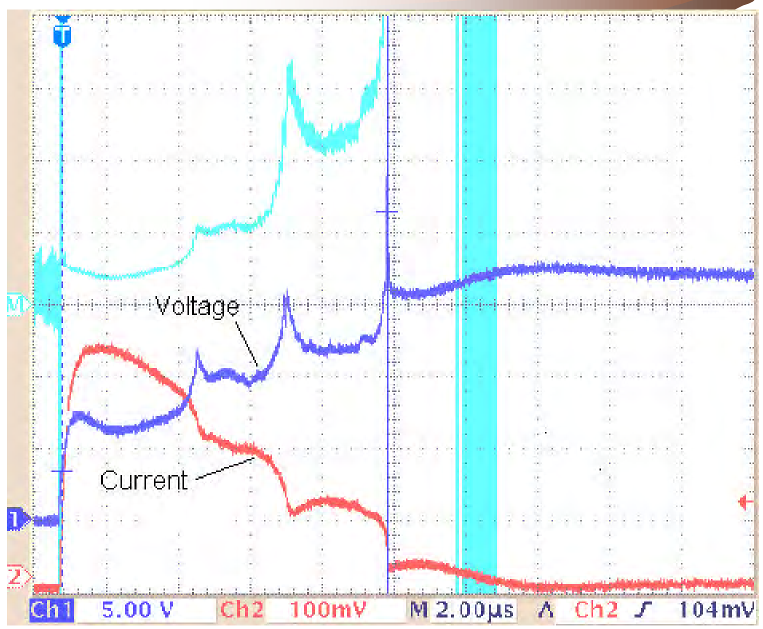
4cm

4cm

Firing Current Waveforms

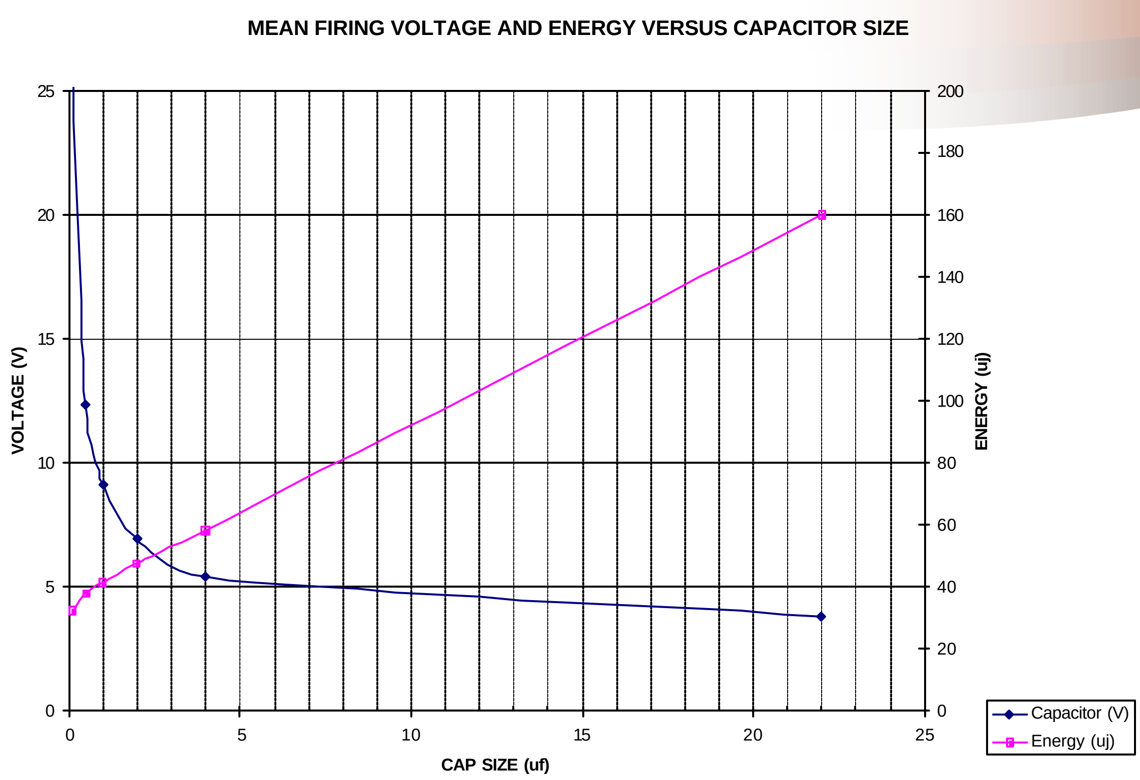


Typical Firing Trace of a Composite Bridge
(30µm bridge)



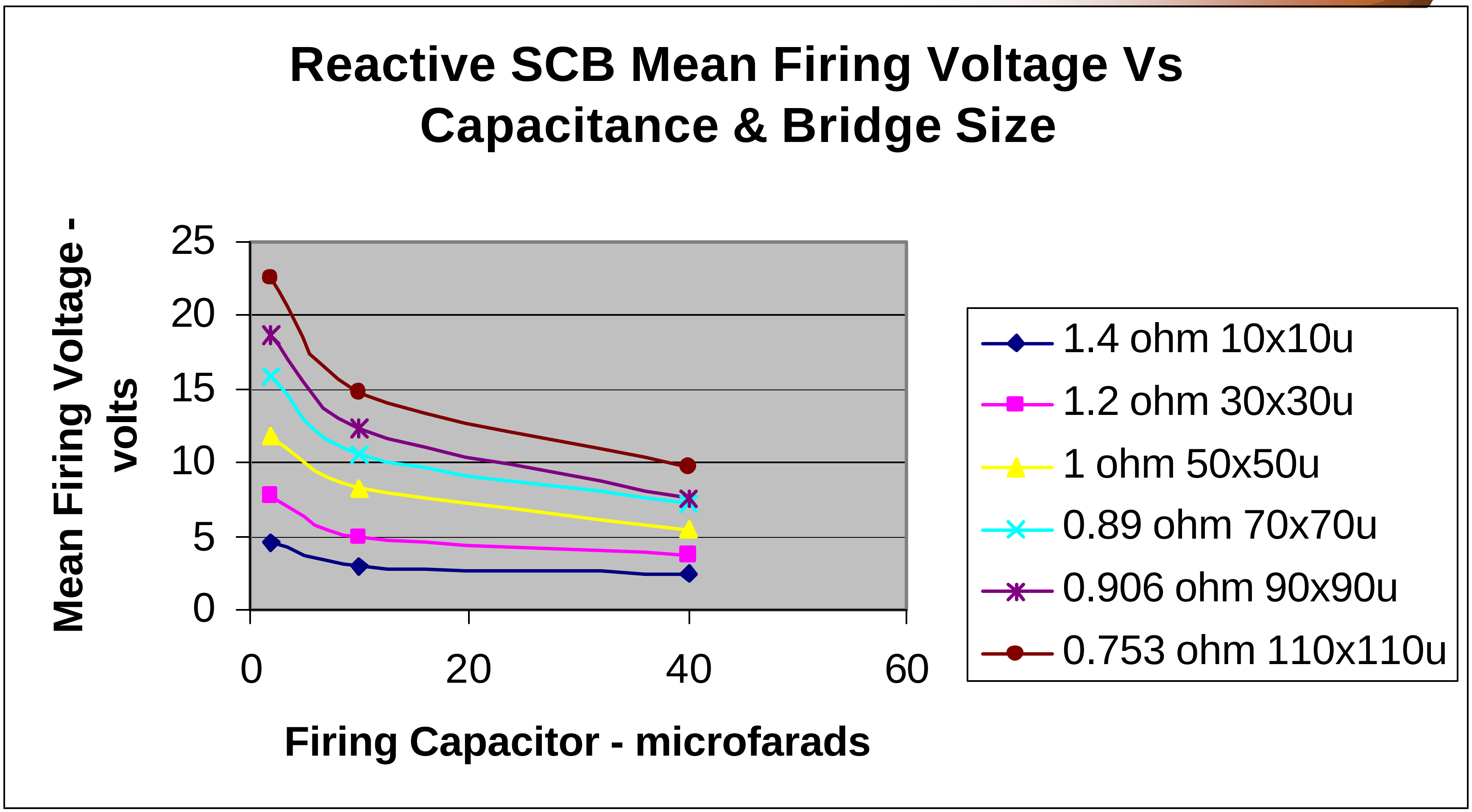
Typical Firing Trace of a Laminate Bridge
(30µm bridge)

Firing Characteristics of Laminated Bridge with 5W ESR

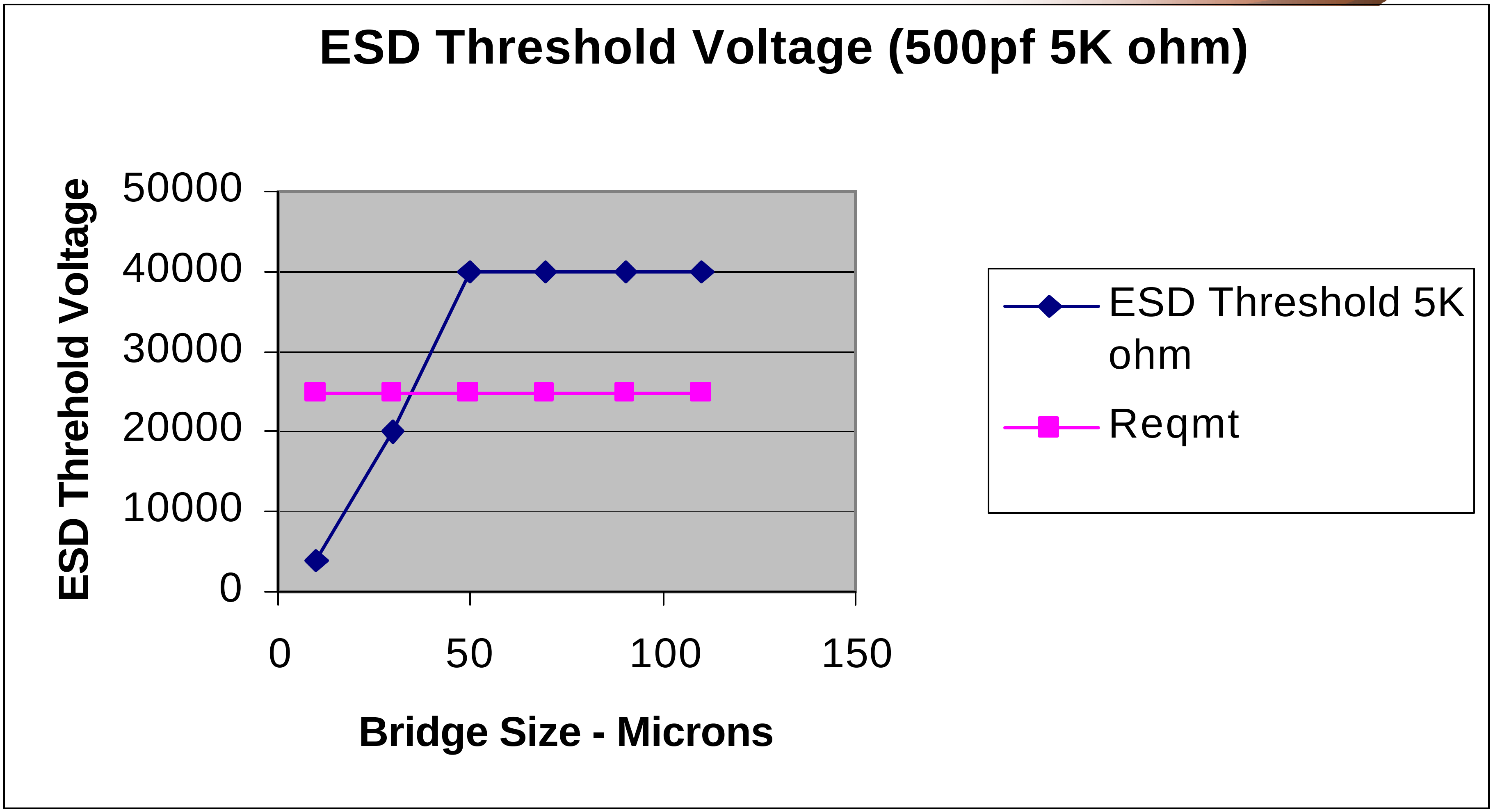


A plot of firing voltage and energy for a 20 µm Laminated bridge

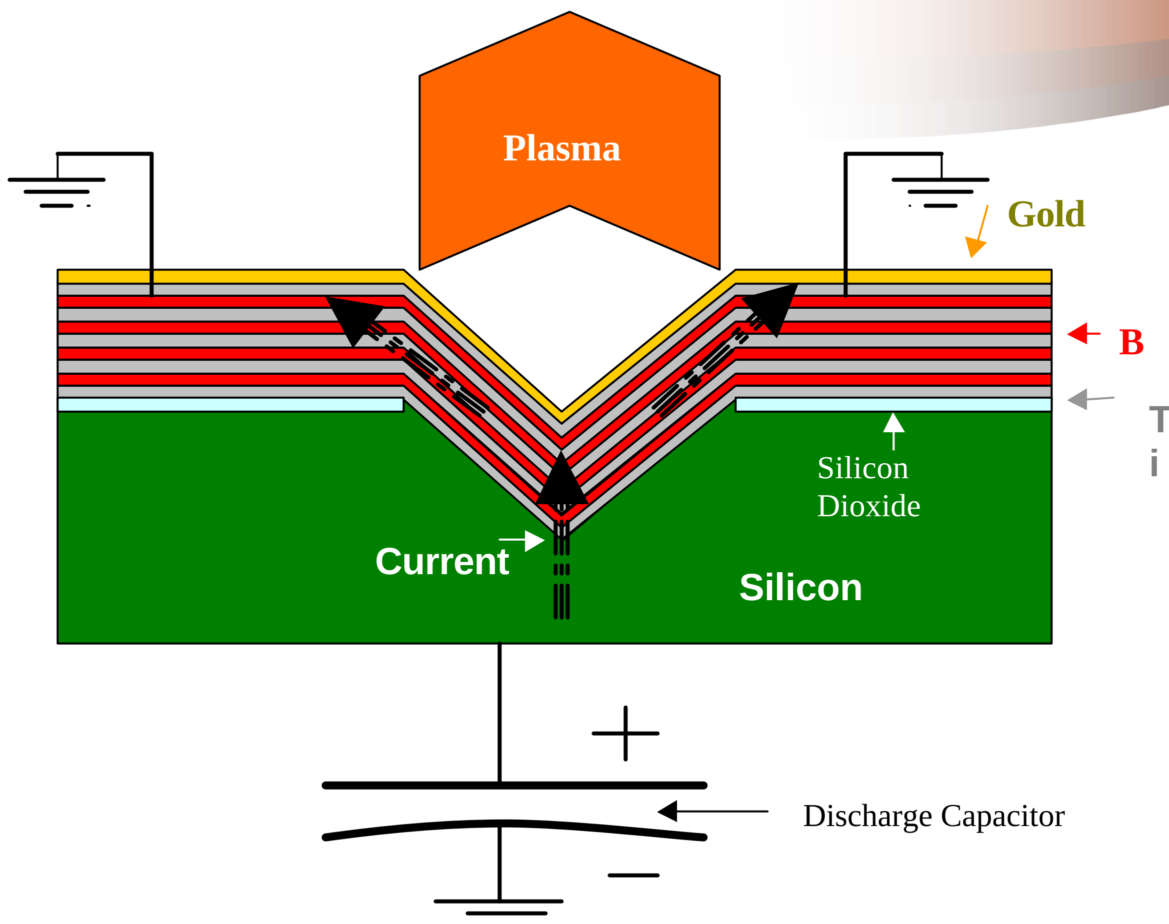
Firing Data for Laminated Bridge



ESD Results for Laminated Bridge



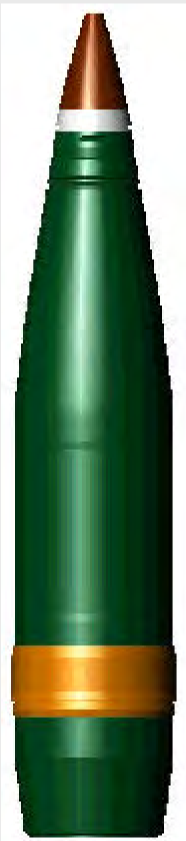
Integrated Shaped-Charge

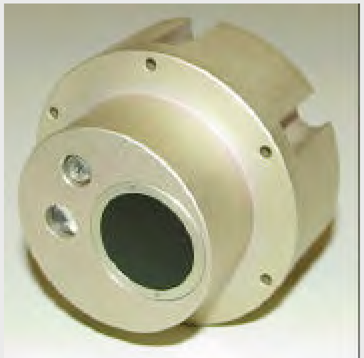


Conclusion

- Devices Fabricated Using Conventional Techniques
- Demonstrates Lower Firing Energy
- Diodes Protect Against ESD Events
- Reliably Fires in Less Than 1μsec
- Plasma Output Capable of Jumping a Gap
- Very Economical for Large Volumes

Fuzing at Dahlgren

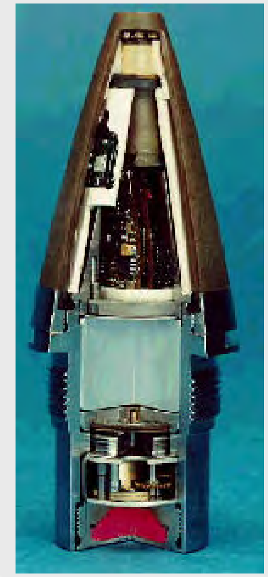


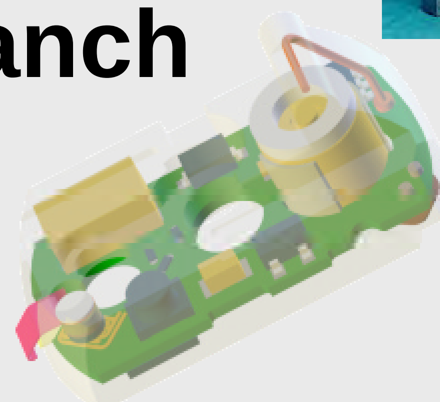


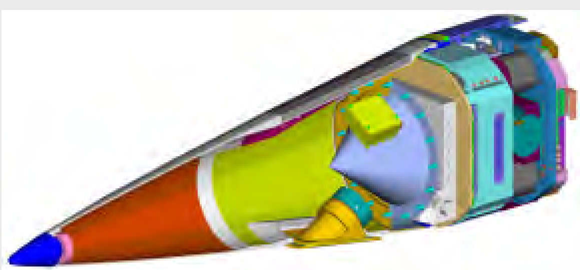
Michael A. Till

NSWC Dahlgren Division

G34, Fuze Branch





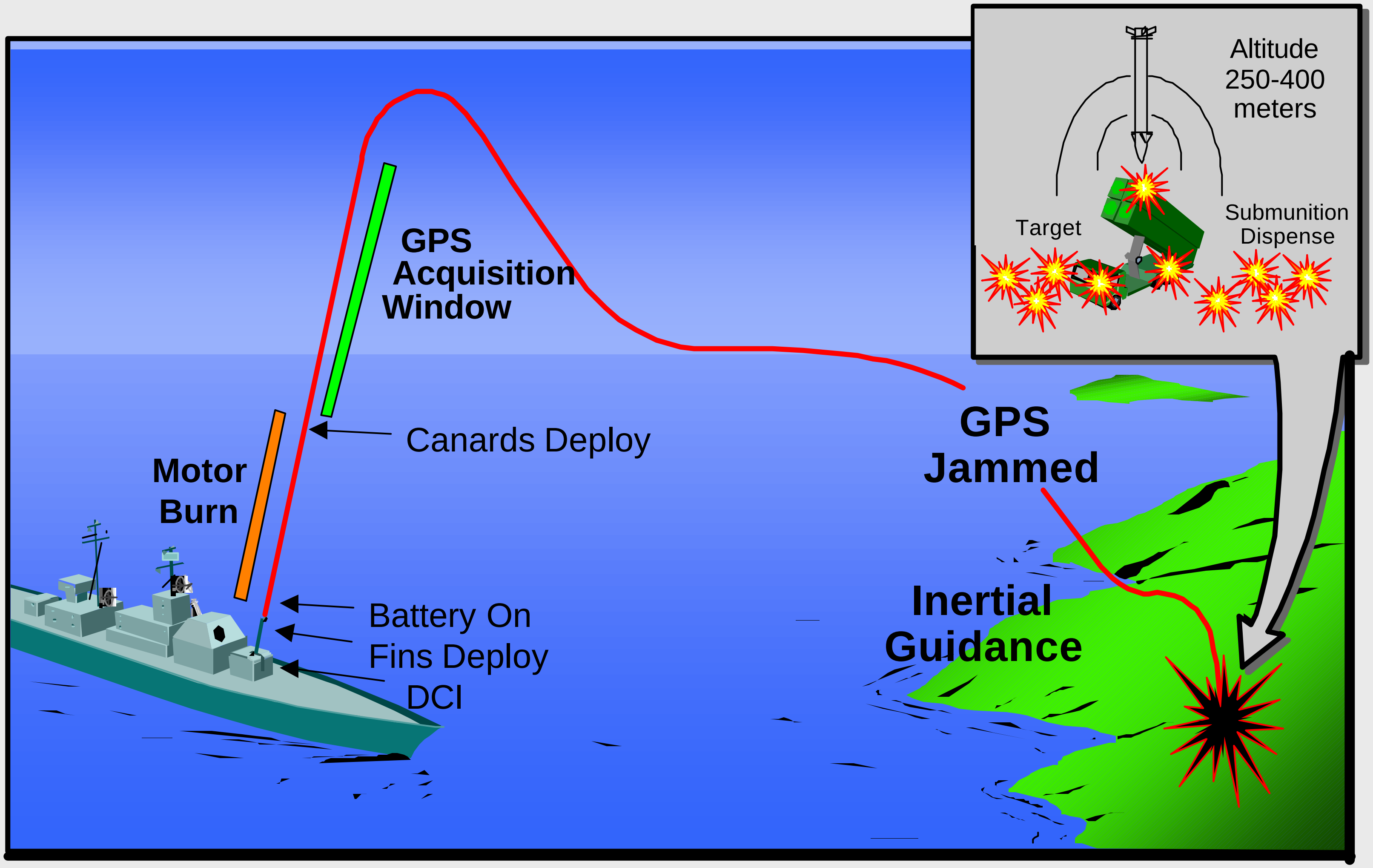


ERGM System Description

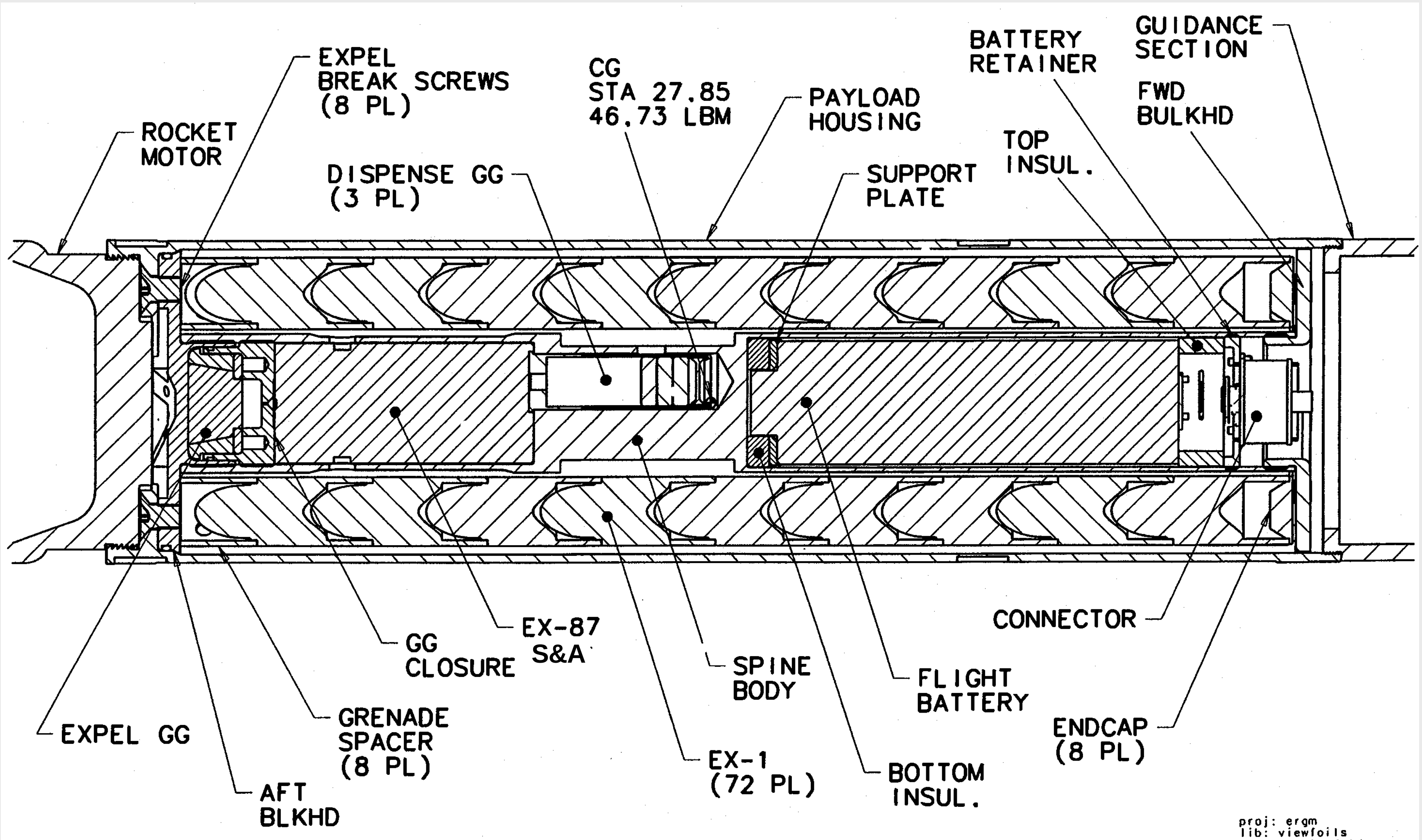
- Roll-Attitude Controlled Airframe
- Vertical Endgame Trajectory

- Length: 61 Inches
- Weight: 110 Pounds
- Fuze: Integral, GPS Initiated
- Guidance: GPS/INS
- Accuracy: <20m CEP
- Payload: Submunitions
  - 72 EX-1s (Modified M80s)
  - Self Destruct Fuze (M234)
- Propulsion: Rocket Motor
- Range Objective: 63 nmi
- Prop Charge: 18 MJ
- Loading: Double Ram

ERGM Mission Profile



ERGM Payload Section



ERGM Fuzing Status

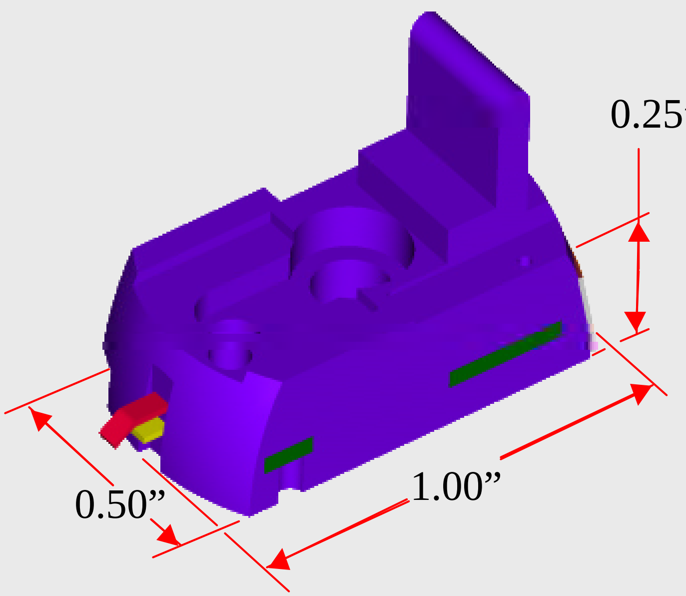
- **EX-87 Mod 1 S&A:**
  - Completed Design Validation Tests (DVT)
  - Successfully Fired 3 in Canister Projectiles
  - Successful Fired in Dynamic Dispense Air Drop Test (DD-1)
  - Lessons Learned from DVT have been Incorporated
- **Near Term Testing:**
  - S&A Qualification (July 01)
  - Piston Actuator Component Qualification (June 01)
  - Dynamic Dispense Gun Fire (May 01)
- **M234 E1 Self-Destruct Fuze:**

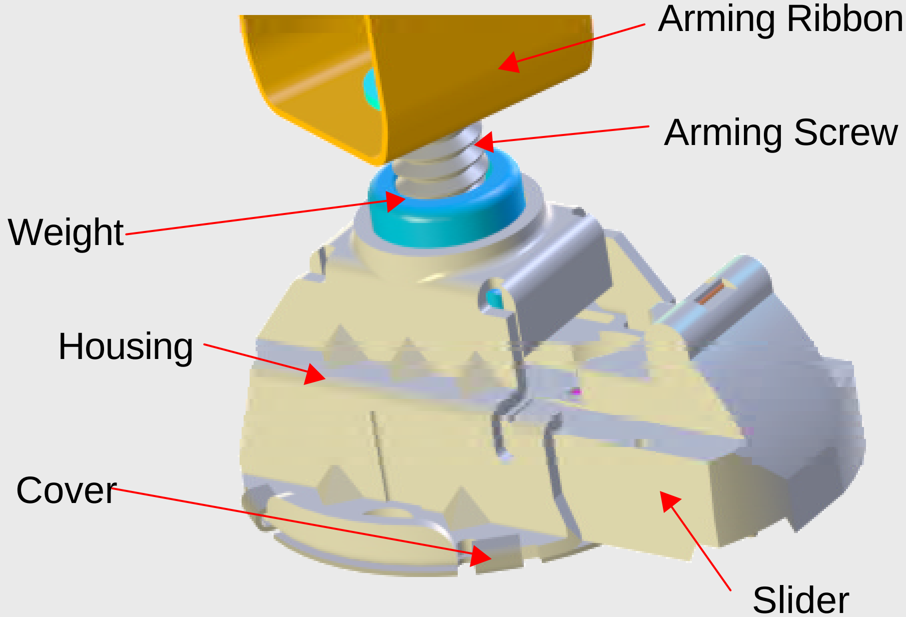
ERGM Fuzing Status

- M234 E1 Self-Destruct Fuze:
  - DD-1 Test (YPG, 18 Aug 00)
    - Slight Over-Test Condition (Expel/Dispense Altitude Too Low)
    - 13 Primary Mode Failures (82% Successfully Armed)
    - 0 ERGM Shunt Removal Failures (100% Successfully Armed)
    - 14 Spiral Flag Failures (81% Successfully Armed)
  - Additional Improvements Incorporated for Dynamic Dispense Gunfire Test (DD-2) Scheduled for early May '01

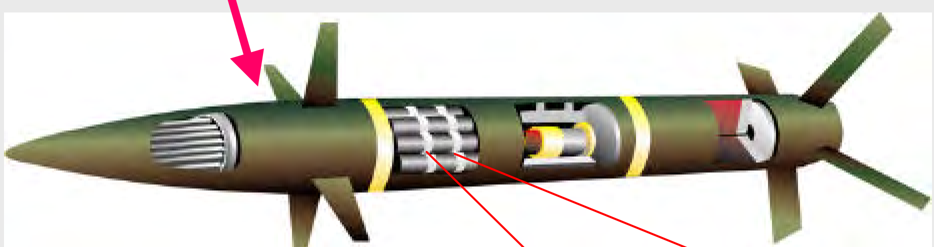
M80 PIP Objective

- To package the electronics and mechanical components of the Proximity Fuze in the shape and size of the current M234 SD Slider for the M80 Submunition for ERGM
  - One-for-One replacement of current Slider





MK 45 MOD 4

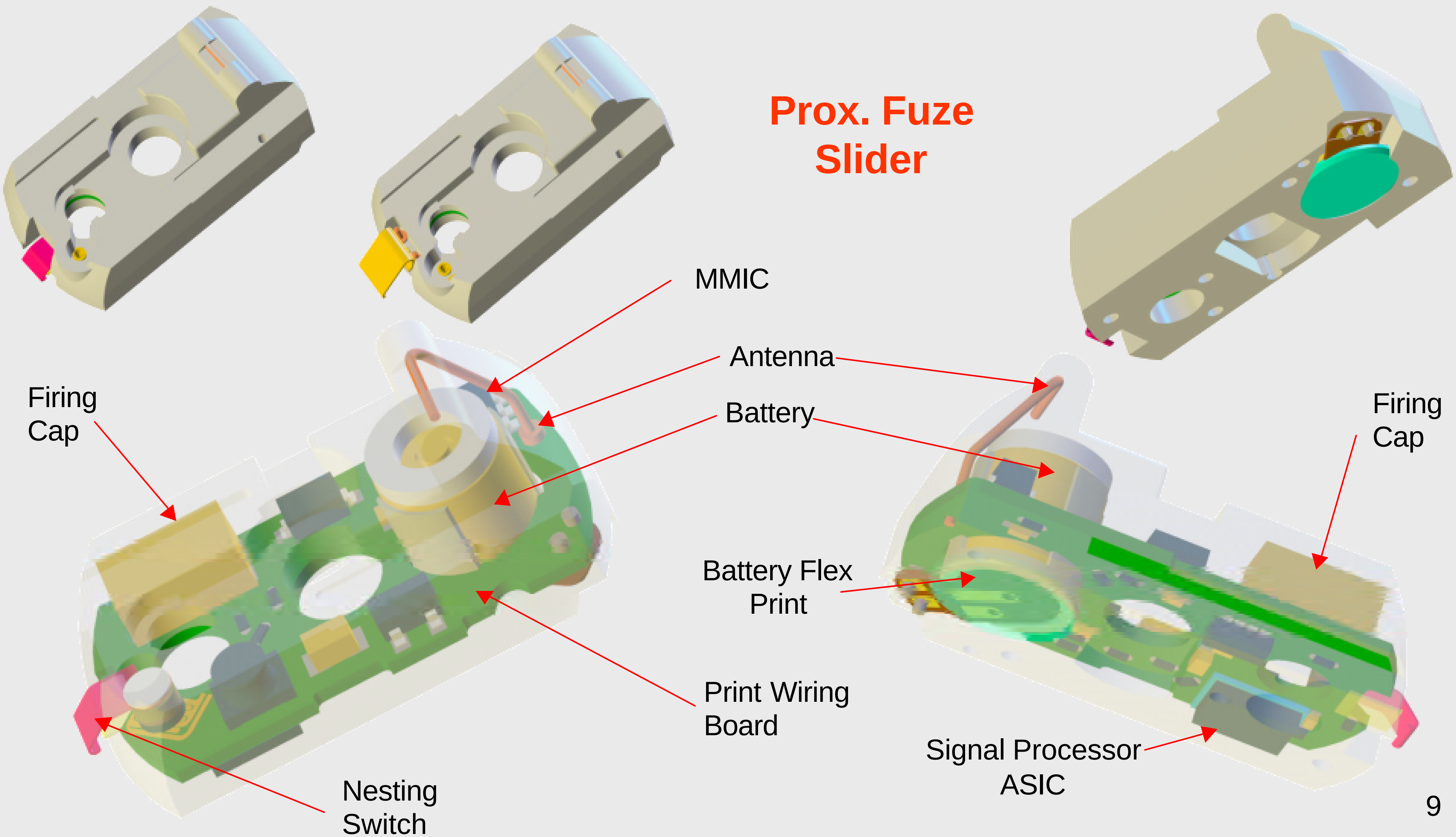


ERGM

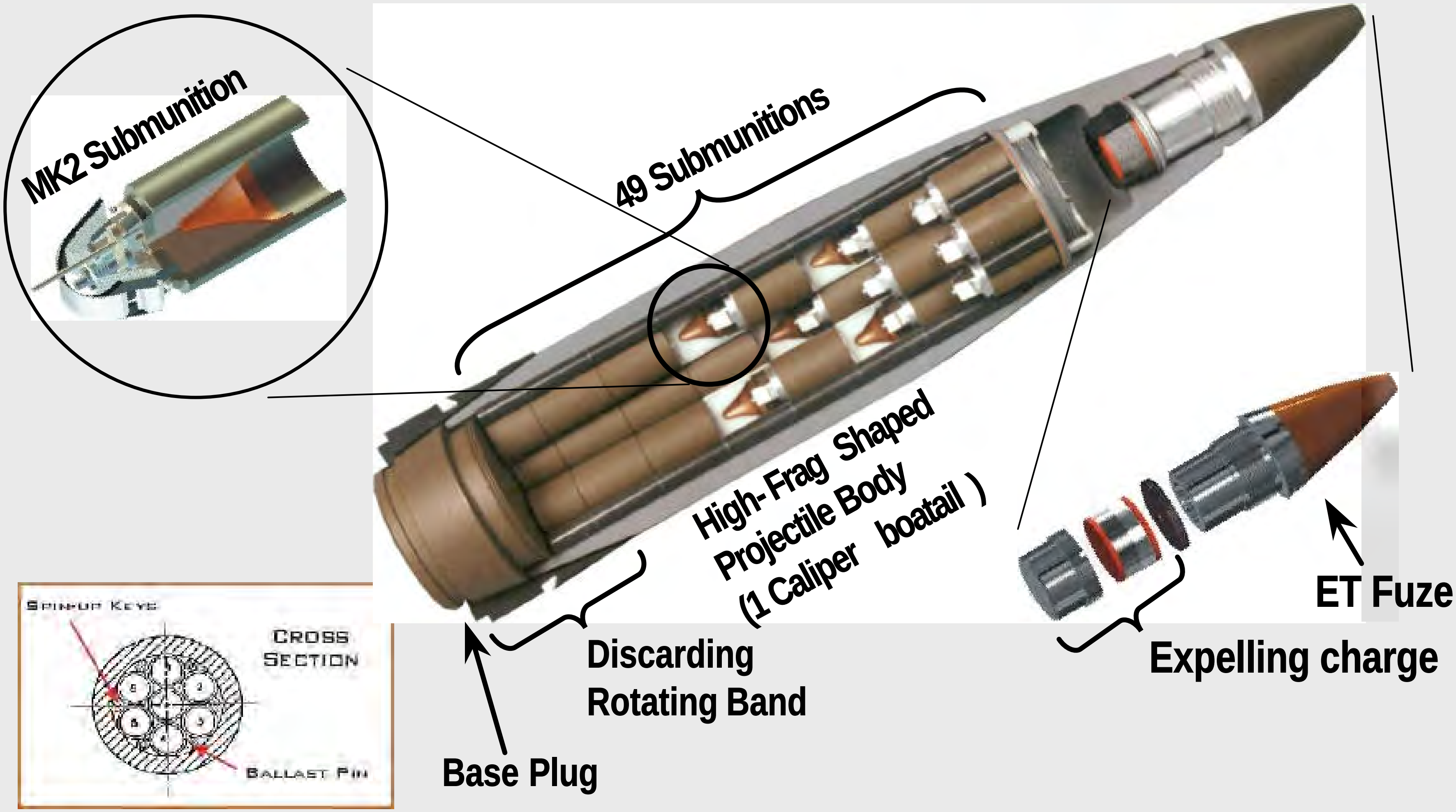
EX 3

Proximity Fuze

Major Component Layout



Navy 5” Cargo Projectile



M80 Grenade Fuze, M223 Safety Modification

- **Design challenge:**
  - **Add a safety feature to the grenade for the 5” cargo round**
  - **Minimal cost and ASAP - we’re already in production: 700,000 fuzes made**
  - **Requirements driven from WSESRB letter (objective) & PEO “acceptance of risk” (threshold)**

Resolution Efforts (Grenades already purchased)

Numerous add-on and redesign fixes were sketched and analyzed, then down selected a number of add-on fixes

Slow Cook-off Simulated Magazine Set-up

Thermocoupled Grenades

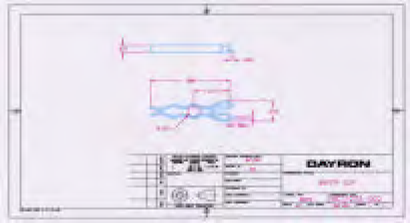
Shrink Tubing

Program has invested over $1.5M to date to resolve issue

Dayron Setback Clip

Dayron Dual Mode Clip

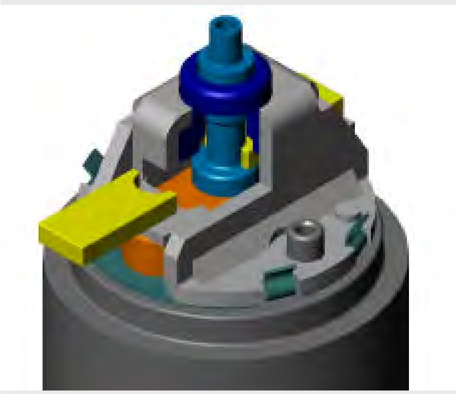
Engineering Concept



Metal spin clip line of designs stopped by WSESRB letter

Resolution Efforts Downselect

Dual Meltable Spin Locks



- 1st tests show both significantly improve safety
- Solutions will meet 95% of the WSESRB concerns. May still leave 1 armed grenade plus 2 w/o an extra lock post cook-off
- Reliability testing and final downselect in May 01
- Cargo Program review at end of month. May change design course & require a 100% solution

Single Meltable Spin Lock

BULOVA
TECHNOLOGIES LLC

NAVSEA
DAHLGREN

MK 432 ELECTRONIC TIME FUZE

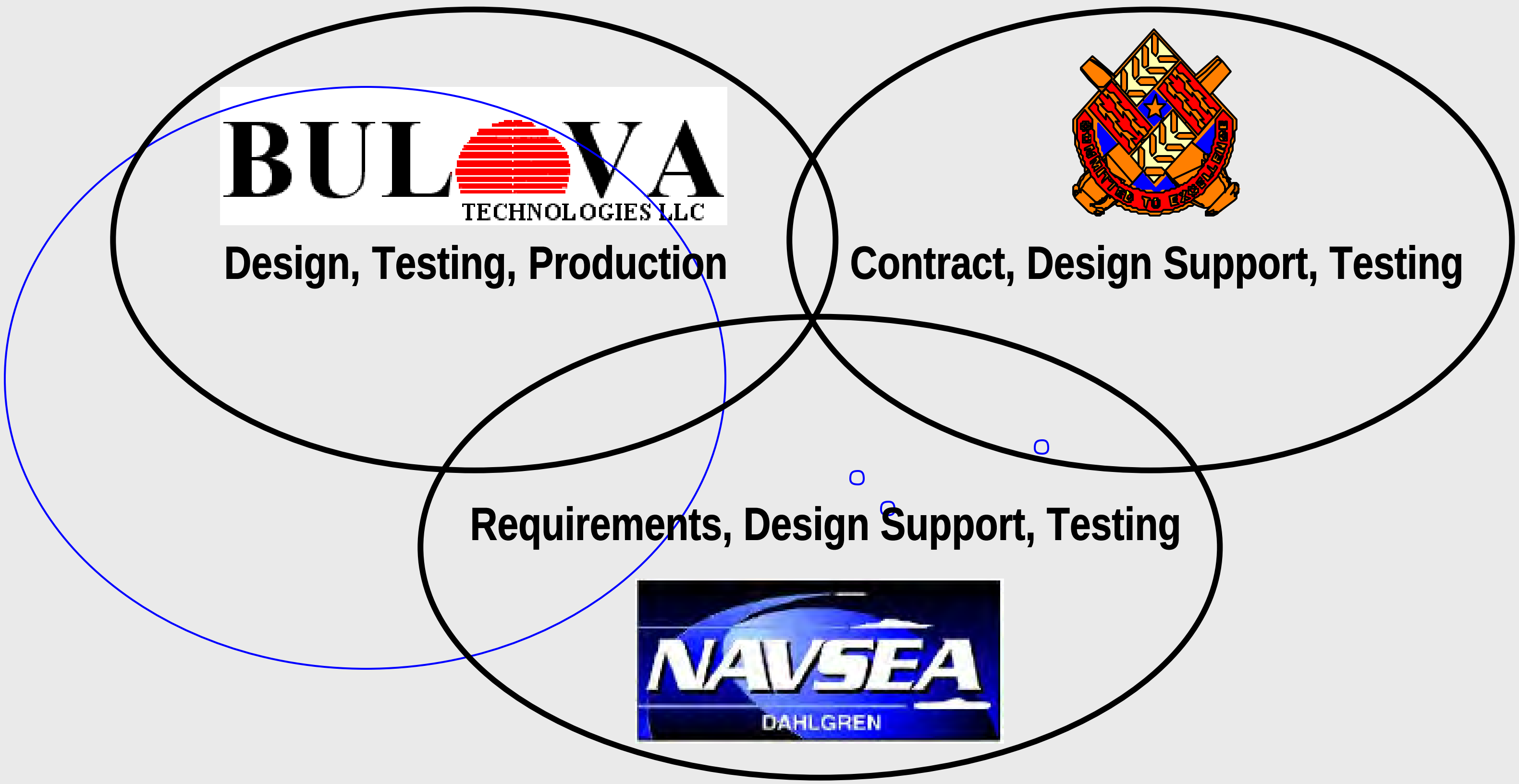
A New Fuze for the US Navy

TACOM
Mobility and Firepower
for America's Army

AMERICA'S ARSENAL FOR THE BRAVE

COMMITTED TO EXCELLENCE

Team Approach



Navalization of the M762A1

- Inductive Set Compatibility
- Battery Activation
- Targets
- Remove PD back-up
- EEE improvements
- IM

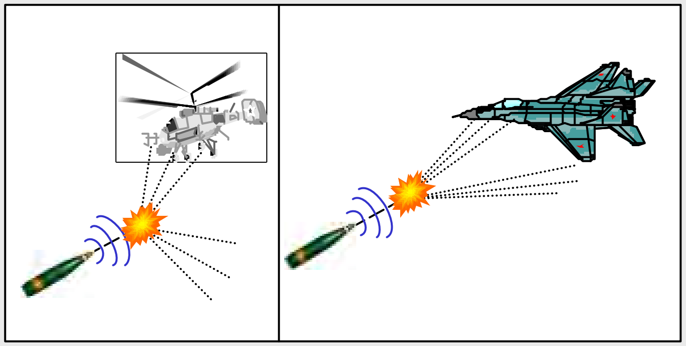
Qualification

- Completed in 9 months:
  - 400 fuzes delivered
  - Successful gun firings
- Qualification Completed Summer 2001
- Production Scheduled to begin July 2001
- 14,600 Fuzes Delivered October 2001

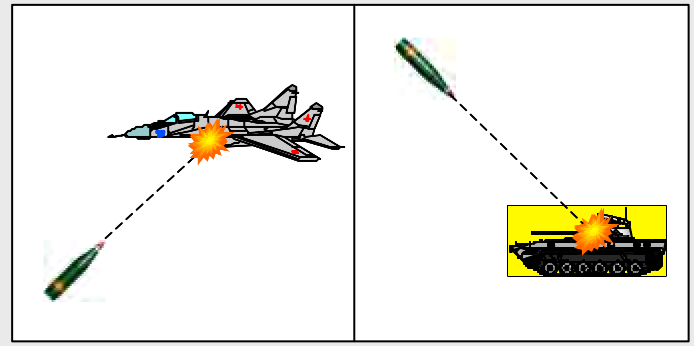
Multi-function Fuze (MFF)

MFF Operational Modes

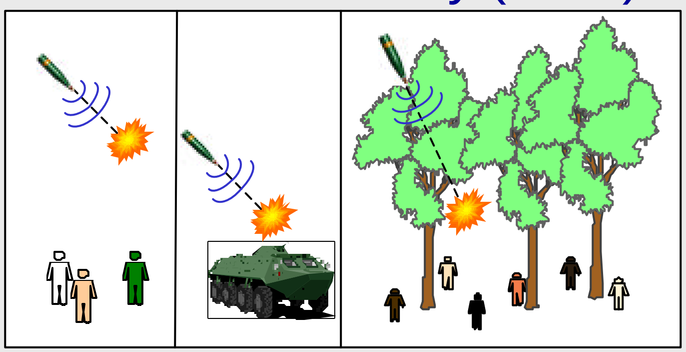
Air Proximity (AIR)



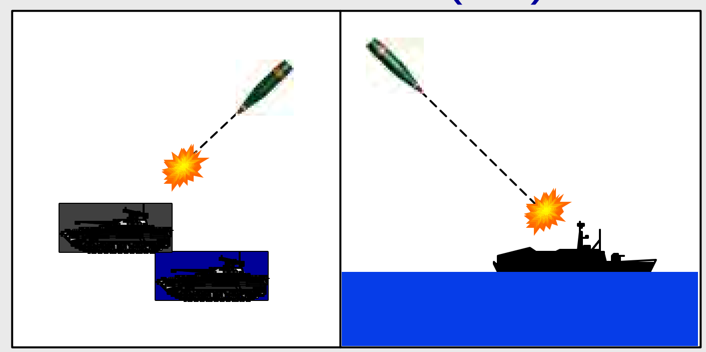
Point Detonating (PD)



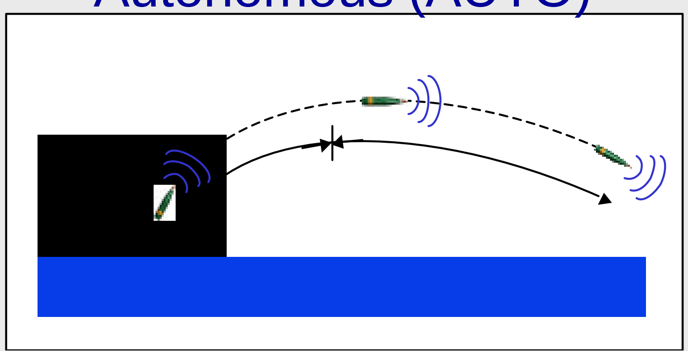
Surface Proximity (HOB)



Electronic Time (ET)



Autonomous (AUTO)



Replaces VT, CVT, MT & PD fuzes on HE rounds.
Simplifies logistics.
Uses IM Explosives.

Multiplies effectiveness of ship's magazine.
Improves fuze performance, accuracy, reliability & versatility.

MFF LRIP

- IPT: NSWC Dahlgren, NSWC Crane & ATK
  - Performance Specification
- Production at Alliant Precision Fuze Company, L.L.C in Janesville, WI
- LRIP ~9500 fuzes in 3 lots
- Options for another 6000 to 12000
- Pre-First Article performance
  - Twice as sensitive as MK 418 VT-RF fuze against the same air target
  - E&MD performance & production issues resolved

MFF Schedule

- New Program Schedule Approved
- Updating the ORD and TEMP
- TECHEVAL 3rd Qtr FY01
- OPEVAL 4th Qtr FY01
- Milestone III Decision 1st Qtr FY02
- LRIP 1st Lot delivered 2nd Qtr FY02
- IOC 1st HE-MF rounds delivered 2rd Qtr FY02
- FOT&E for 5in/62 Gun Qualification in FY02

MK 419 TECHEVAL

- San Clemente Island, SHOBA, 3rd Qtr FY01
- USS Bunker Hill (CG 52)
- 57 MK 419 Test rounds, 90 rounds total
- Part of First Article
- Test HOB, PD, ET, AUTO(HOB) performance over land and water

MK 419 OPEVAL

- San Clemente Island, SHOBA, 4th Qtr FY01
- USS Bunker Hill (CG 52)
- 170 MK 419 Test rounds, 200+ rounds total
- Test AIR, HOB, PD, ET, AUTO(HOB), AUTO(AIR) performance over land and water
- Towed RF air target

MFF Cost Reduction RF System

- MMIC Receiver
  - Plastic encapsulation vs. ceramic pkg
  - Adjust frequency to reduce tuning effort
  - Align with optimum antenna and transmitter frequencies
- MMIC Transmitter
  - Plastic encapsulation
  - Frequency tweak if required
- Antenna
  - Improve dielectric material properties to enhance producibility
  - Decrease raw material cost

MFF Cost Reduction Battery

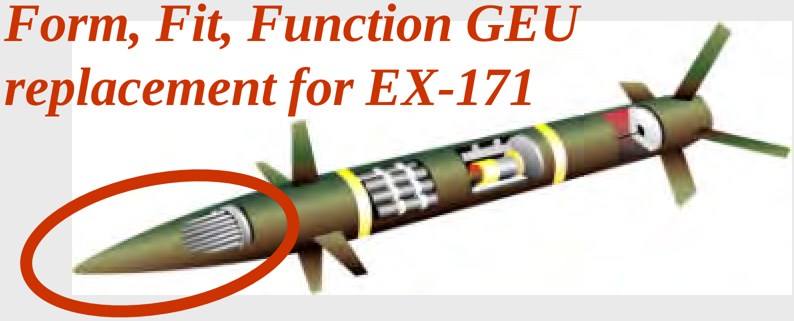
- Use MOFA battery with minimal modification
  - Failed to meet performance requirements
- European battery conference held to identify potential battery sources

Technical Objectives

- Develop an alternative Low Cost Guidance Electronics Unit (LCGEU) for the EX171 Extended Range Guided Munition (ERGM)
  - design as a form, fit, & function replacement for existing ERGM GEU
  - identify & select performance trades versus affordability
  - demonstrate performance via a series of guided flight tests

LOW COST GEU

Form, Fit, Function GEU replacement for EX-171



Technical Objectives (Contd)

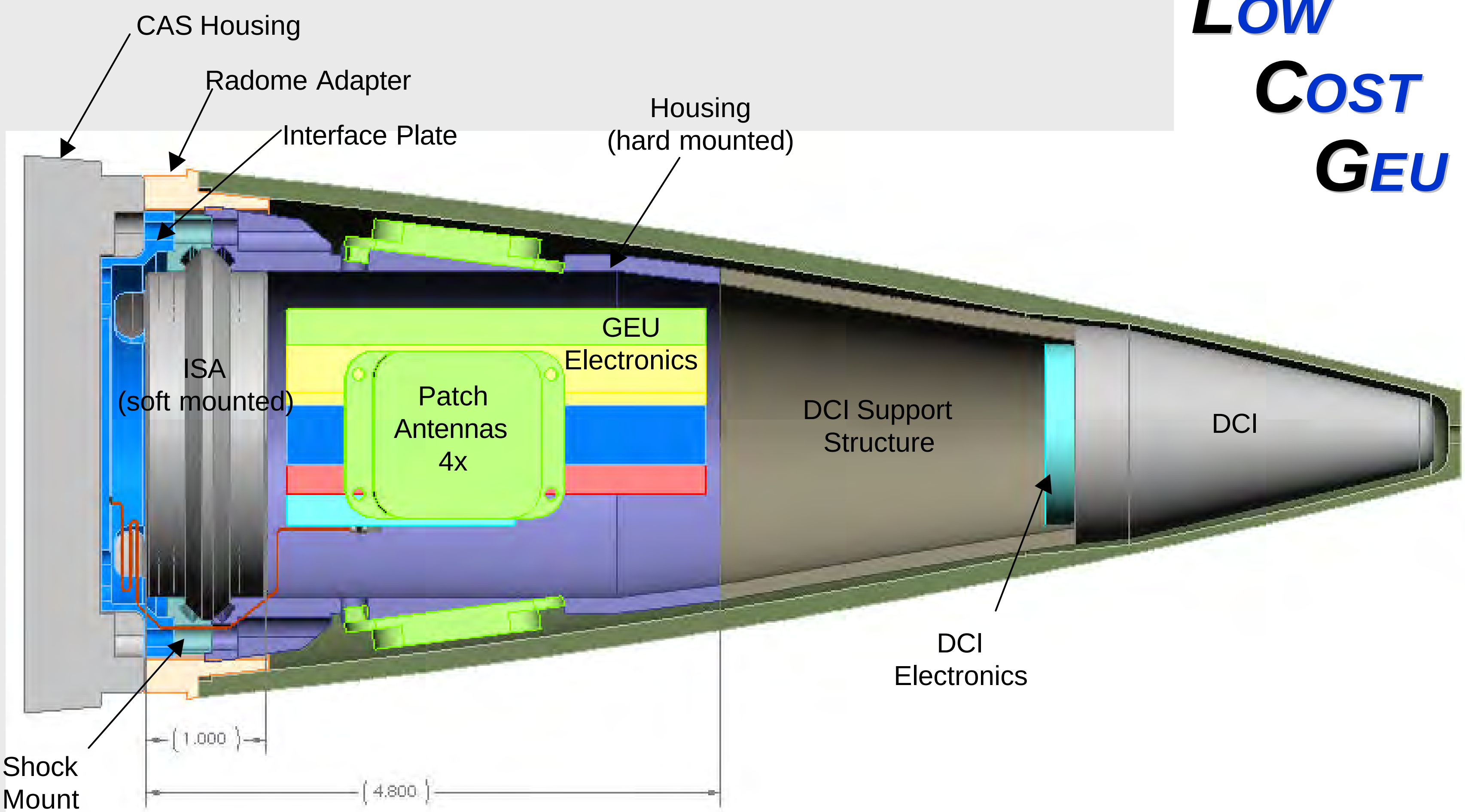
- Prepare for transition to future EMD phase
  - Work closely with Rockwell / Collins (EMD prime) to develop cost as independent variable in LCGEU design
  - Deliver complete HW/ SW documentation package
  - Identify future production cost reduction opportunities

LOW COST GEU

Form, Fit, Function GEU replacement for EX-171

Baseline Mechanical Design

LOW COST GEU



Draper Proprietary

Standard Missile - 4 Height of Burst Fuze

Integrated Product Team (IPT) Assembled to Select a Height of Burst (HOB) Sensor and Incorporate as Primary Fuze for LASM

Raytheon

- HOB IPT LEAD
- MISSILE DESIGNER

THE JOHNS HOPKINS UNIVERSITY APL

- TDA, REQUIREMENTS DEFINITION
- MODELING, TESTING

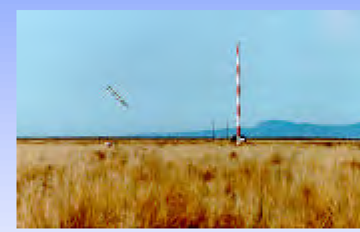
NAVSEA DAHLGREN

- GOVERNMENT FUZE EXPERT
- BAA

Mission Overview

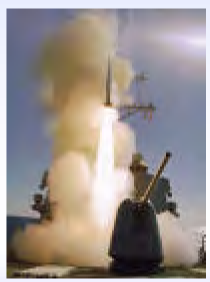
Midcourse Phase
- Missile Flies to Vicinity of Command Point
- Guidance Commands Generated Within Missile
- Inertial Instrument Errors Reduced by In-Flight GPS Updating

Boost Phase
- Pitch over Guidance (VLS only)
- Missile Achieves Supersonic Speed



Warhead Initiation Phase
- Flight Path Angle Control
- Ground Height of Burst Calculated
- Inertial Guidance During GPS Jamming

Targeting Data
- Forward Observer
- UAV
- Satellite



VLS

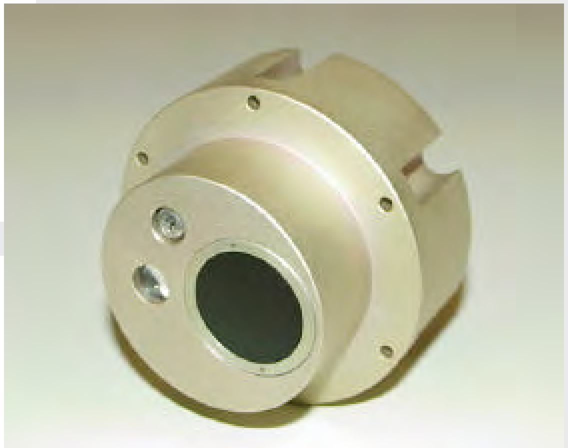
Initialization
- Initialization & Target Data Supplied
- GPS Initialization

HOB Sensor Selection

- **Identify Candidate Sensors**
  - Broad Agency Announcement (BAA)
  - Previous Trade Studies
  - Recommendations from Team Members
  - 18 Sensors from 12 Vendors Identified
- **Sensors Fell into 3 Classes: Radio Frequency, Electro-Optical, Mechanical**
- **Down-select to Set of Sensors Meeting Minimum Requirements**
- **Used Quality Functional Deployment Matrix for Comprehensive Comparison of Down-selected Sensors**
  - Evaluation Criteria Split Between Cost and Performance
  - Relative Weights of Evaluation Criteria Determined by Team Consensus
  - Scores Awarded Each Sensor Determined by Team Consensus

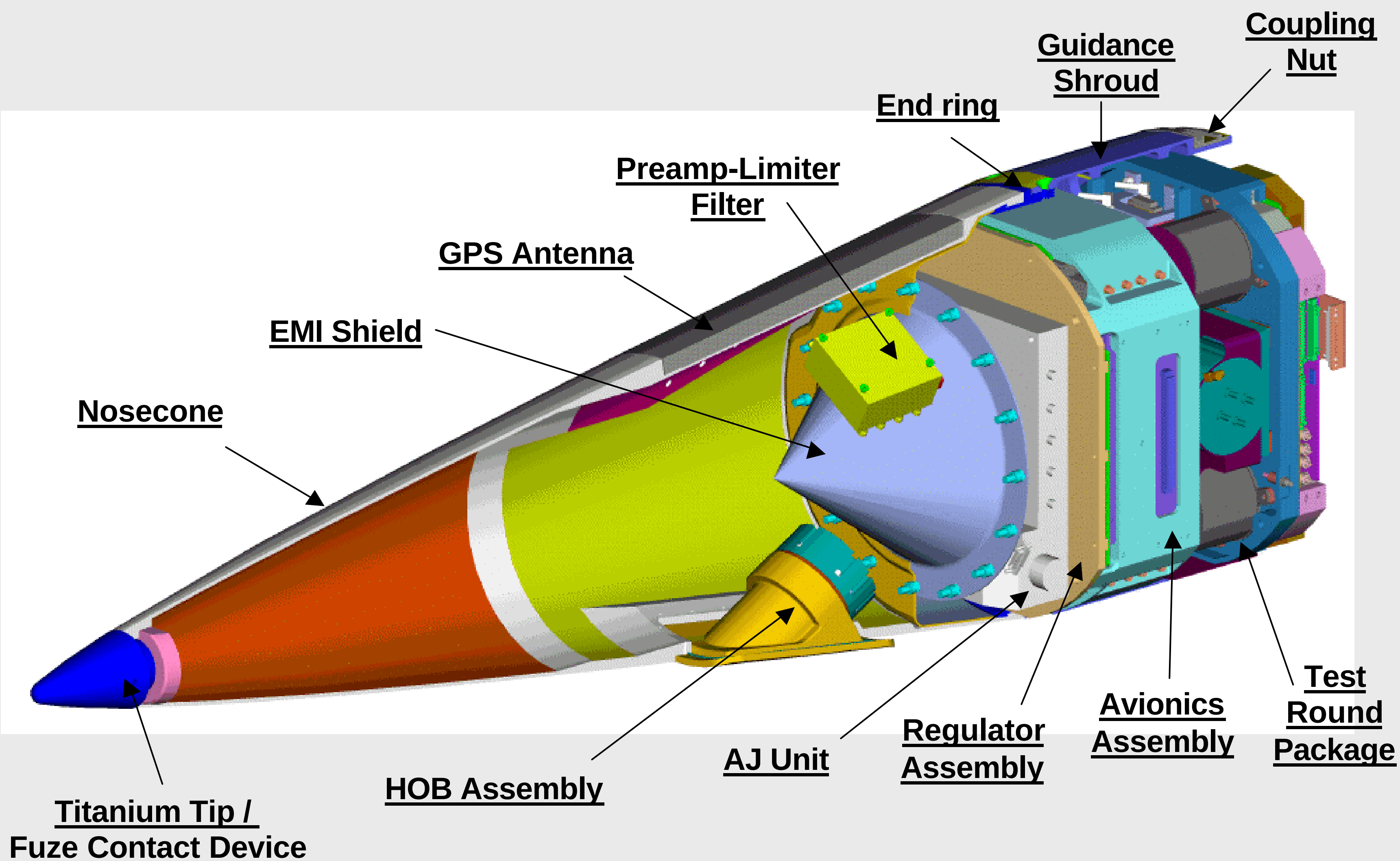
HOB Sensor

- Gen III - LASM Configuration
- Near IR Pulsed Diode Laser
- Low Cost, Rugged, Low Power, Array Logic, Microprocessor w/ EEPROM flash Memory, Serial Communication, Continuous Altitude readout, Obscurant Algorithms



- Gen III - Performance
- Cost Effective
- Will Meet Missile Environments
- Meets Clear Air Requirements
- Will Not Pre-trigger on Obscurant
- Will Distinguish Hard Targets from Obscurants
  - Degradation of Performance in Obscurants - TBD
- Mechanically and Electrically Interface with GS
- Adaptive Configuration for Future Growth

GUIDANCE SECTION ASSEMBLY



Summary

- Requirements Defined
- EO Sensor Characterized and Risks Identified With Mitigation Plans
- Preliminary Mechanical Design for HOB Main Assembly Complete
- Analysis and Test Performed

Future Efforts – Course Corrected Fuzes

- Trajectory error management
  - 1-D Corrections: drag chutes, drag fins, etc. to reduce range dispersion
  - 2-D Corrections: canards, pulse dots, etc. to reduce range dispersion and cross-track deflection
- Must not violate NATO standard fuze envelope during pre-flight
  - Ensures minimal impact on round handling equipment and procedures
  - MIL-STD-333B envelope selected
- Range increase not required
- Fielding by FY10

Future Efforts – Low Cost Projectile Fuze Alternatives

- Reduce Fuze Re-procurement Costs
  - Buy Fuzes with Army
    - Navalized MOFA
  - Buy Components with Army
    - Common S&A, battery, detonators
  - New Fuze
    - Low Cost Air Warfare Fuze
  - New Requirements

Issue #1: Batteries

- In the last few years, DOD has lost significant manufacturing and design ability to make batteries for gun fired munitions
  - Reduction in the last 10-15 years
    - Govt battery R&D personnel: approx 90% loss
    - Contractor companies: from 15 to 3
- The government has not maintained the expertise
- The contractors can not maintain the expertise
- No fundamental R&D conducted in the last 10 years in liquid reserve technology
- Applied chemical engineering has been conducted in a limited way on select programs with very limited success
  - Based on 15-20 year old technology

Impact to Navy Programs

- JMPSIB-IPT
  - Dahlgren is the Navy's lead on the Joint Service IPT
- MK 419 MFF Battery
  - MK 44 Lead-chemistry battery unproducible within USA
  - No direct replacement
    - Lithium replacement program did not meet requirements
    - Investigating two European batteries
      - Lithium Chemistry
      - Lead Chemistry

Miniature Liquid RE

- EP, ATK, KDI have no success or limited experience in the cutting edge of power sources technology
- Major concern to ERGM program for both submunition programs
  - M234 SDF
  - EX 433 Prox Fuze

Objectives

- Current Navy Projectile Battery Requirements
  - ERGM
    - 2 System batteries (1 thermal reserve, 1 liquid reserve)
    - 72 Submunition batteries
  - MK 419 - MFF
  - MK 418/MK 417 - VT-RF
  - MK 404 - VT-IR
  - EX 432 - ET

- Future Naval Gun launched projectiles requiring a power source
  - GPS Rounds
  - Best Buy - GPS, 100nmi
  - Badger - GPS, Hypersonic projectile
  - MRO Mission Responsive Ordnance
  - AGS munitions

Issue #2: Submunitions

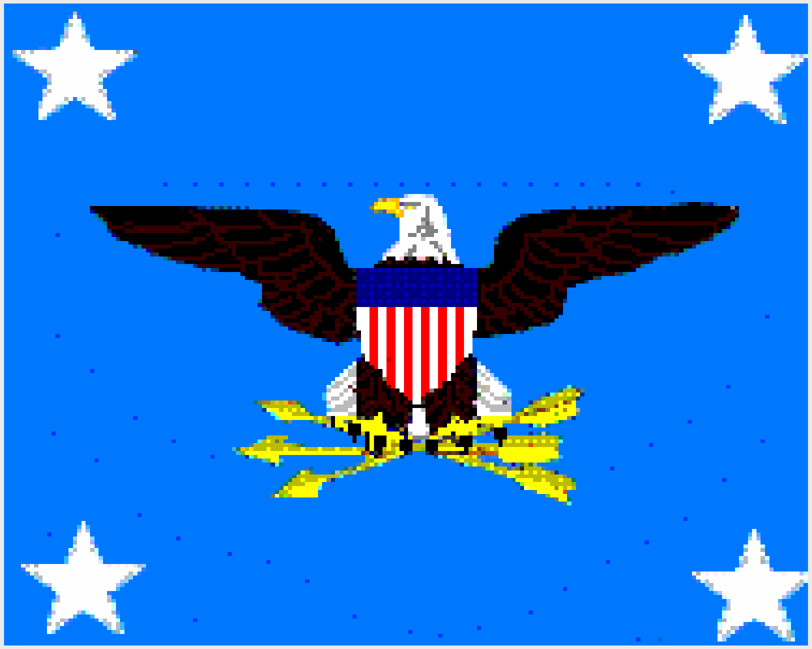
"On April 24, five children playing with colorful unexploded submunitions were reported killed, and two injured, near Doganovic in southern Kosovo."
-Steve Goose, program director of Human Rights Watch's arms division as reported in the Washington Post, Saturday, June 19, 1999; Page A19

"PRISTINA, Kosovo, May 22 -- One boy was killed and two other children were seriously wounded by a cluster bomb on Sunday..."
-Carlotta Gall; published on Tuesday, May 23, 2000 in the New York Times

"Submunition weapons employment in Southwest Asia and Kosovo, and major theater war modeling, have revealed a significant unexploded ordnance (UXO) concern."
-William Cohen, former U.S. Secretary of Defense in a memorandum dated 10 January, 2001

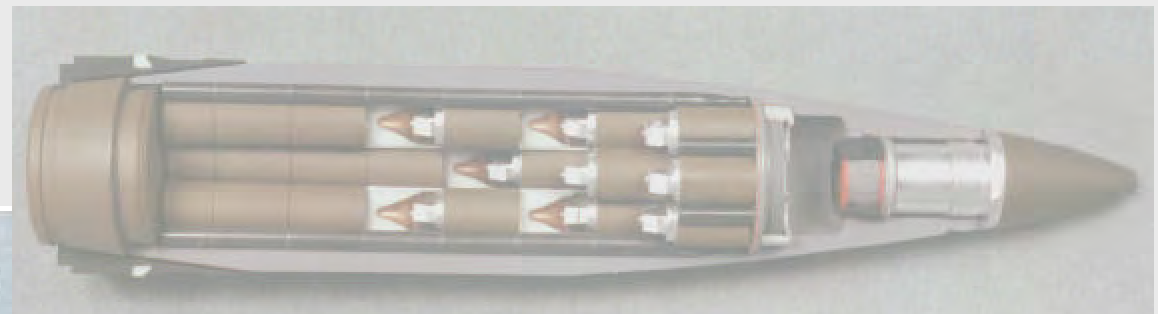
SecDef Memorandum

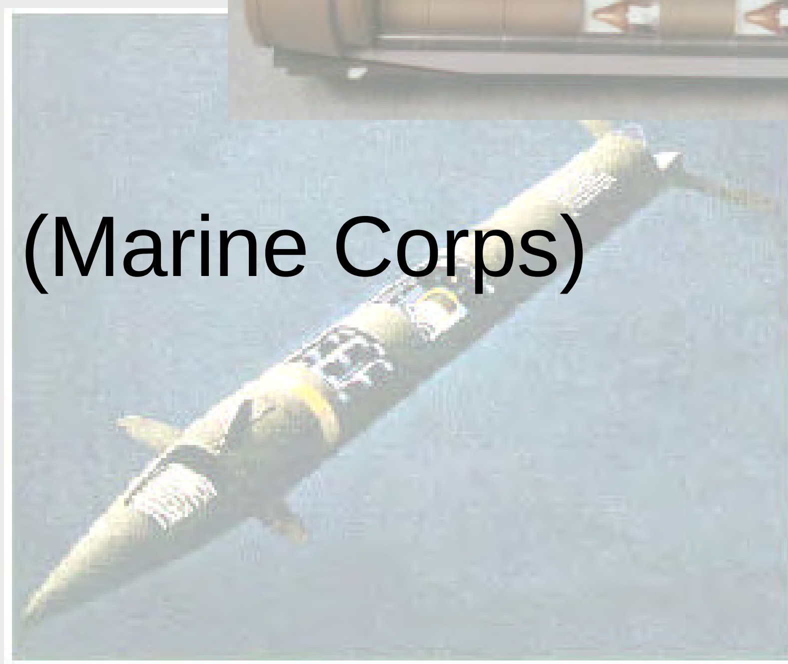
- “It is the policy of the DoD to reduce overall UXO…
- “…the desire is to field future submunitions with a 99% or higher functioning rate.”
- “Submunition functioning rates may be lower under operational conditions…”
- “Services may retain ‘legacy’ submunitions…”
- “Waivers to this policy…shall require approval by the JROC.”

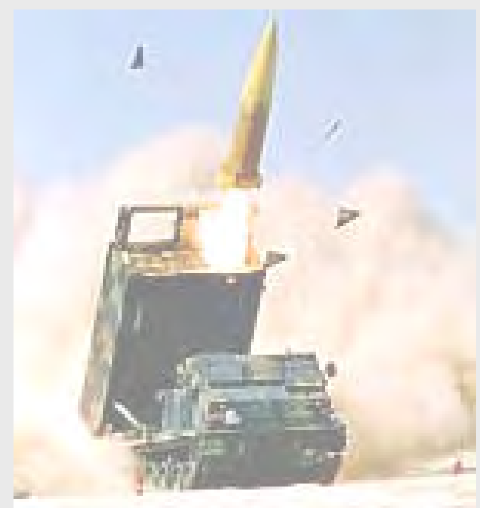


Navy Programs Affected

- ERGM
- Cargo
- MRO
- MLRS (Marine Corps)







What's Next?

- Community Consensus on meaning of memorandum
  - "function"
  - "rates may be lower under operational conditions"
  - "waivers"
  - Safe UXO vs. "function"
- Evaluate Alternatives
  - Technology Investments – redundancy, miniaturization, reduced safety
  - Unitary Warheads – need valid lethality models to make comparisons

NDIA FUZE CONFERENCE

Fuzes for Air Force Unguided and Precision Guided Weapons

17 April 01

Air Armament Center

AAC/WMG

Eglin AFB, Florida

Mr. Frank Robbins

Director

Precision Strike SPO

OUTLINE

- **Current Weapon Systems**
- **Fuzes: Inventory, Production**
- **Challenges For Today’s and Tomorrow’s Fuze Programs**

CURRENT WEAPON SYSTEMS

- AGM-130
- AGM-142
- GBU/EGBU-15
- GBU/EGBU-24/27
- GBU/EGBU-28
- JDAM
- JASSM

AGM-130 MISSILE SYSTEM DESCRIPTION

- Rocket Powered Standoff Precision Guided Missile
  - Man-in-the-Loop (MITL) Terminal Control
  - Interchangeable TV or IR Seekers
  - Interchangeable MK 84 or BLU-109 Penetrator Warhead
  - Fully Autonomous INS/GPS Adverse Weather Capability
- Only U. S. Fighter Launched Air Force Standoff Weapon With 2,000 Pound Warhead
- Integrated on the F-15E Strike Eagle
- Over 100 Used During Operations NORTHERN WATCH SOUTHERN WATCH and ALLIED FORCE

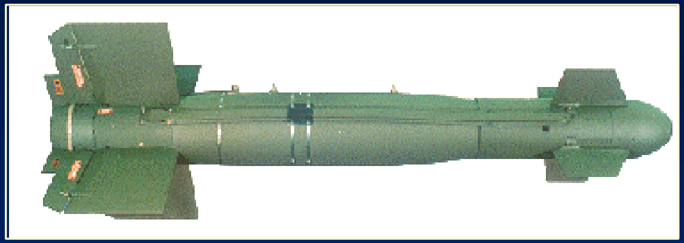
AGM-130 EXPANDED EFFECTIVENESS

- Weapon Improvements
  - Television Guidance Seeker (CCD)
    - Charge Coupled Device
    - Rate Stabilized Platform
    - Correlation Tracker
  - Improved Modular IIR Seeker
    - Focal Plane Array
    - Correlation Tracker
  - Digital Autopilot With GPS/INS
  - Switchable Data Link
  - Performance Enhancements
    - Horizontal Target Attack
    - Envelope Expansion
    - Real Time Information in the Cockpit
  - Support Equipment Improvements

AGM-142 MISSILE SYSTEM DESCRIPTION

- Precision Guided, Standoff Weapon for Use Against High-Value/ Heavily Defended Fixed Targets
  - Data Link Pod Augments Inertial Navigation
  - Interchangeable TV, IIR, or Z-Seeker
  - Interchangeable 750 Lb. Blast/Frag or 800 Lb. Penetrator Warheads
- Only U.S. Bomber Launched Precision Weapon System
- Weapon of Choice for Multiple Allied Fighter Aircraft

GBU-15 MISSILE SYSTEM DESCRIPTION



- Standoff Precision Guided Weapon System For Use Against High-Value Fixed Targets
  – Man-in-the-Loop (MITL) Terminal Control
  – Interchangeable TV or IIR seeker
  – Interchangeable MK 84 or BLU-109 Penetrator Warhead
- Integrated on the F-15E Strike Eagle

EGBU-15 DESCRIPTION

- **Platform - F-15E**
- **Warheads - MK-84/BLU-109**
- **Seekers - TV or IIR**
- **Guidance - Autonomous GPS/INS, Man-in-the-Loop**
- **Data Link - AXQ-14, ZSW-1**

EGBU-15 PROGRAM BACKGROUND

- Chief of Staff, Air Force Directed Quick Reaction Capability Program to Provide Adverse Weather Enhancement to Legacy GBU-15 Weapon System
  - Based upon "Urgent and Compelling Combat Need"
  - Balkans Conflict Depleted Inventory of Precision, Standoff Weapons
- Two-Phased Approach
  - Phase I Program
    - Design, Test, Produce, and Field 100 weapons in 45 days
    - Provide "Interim" integration
  - Phase II Program
    - Design, Test, Produce, and Field 1200 weapons in 12 months
    - Provide "Complete integration"

EGBU-15 STATUS

- Phase I Deliveries Complete; 50 Weapons Delivered in 44 Days; 100 Total Weapons Delivered in 69 Days
- Phase II Deliveries Complete; 1200 Weapons Delivered in 12 Months
  - 5 Development Test and 6 Operational Test Drops -- 11 direct hits!
  - Field Modifications Efforts Completed at Many Locations Worldwide
  - Final Advance Support Equipment, Mission Planning System, and Mission Squadron Trainer Upgrades Nearing Completion
  - Operational Training Completed at Most Operational bases Worldwide

LASER GUIDED WEAPONS

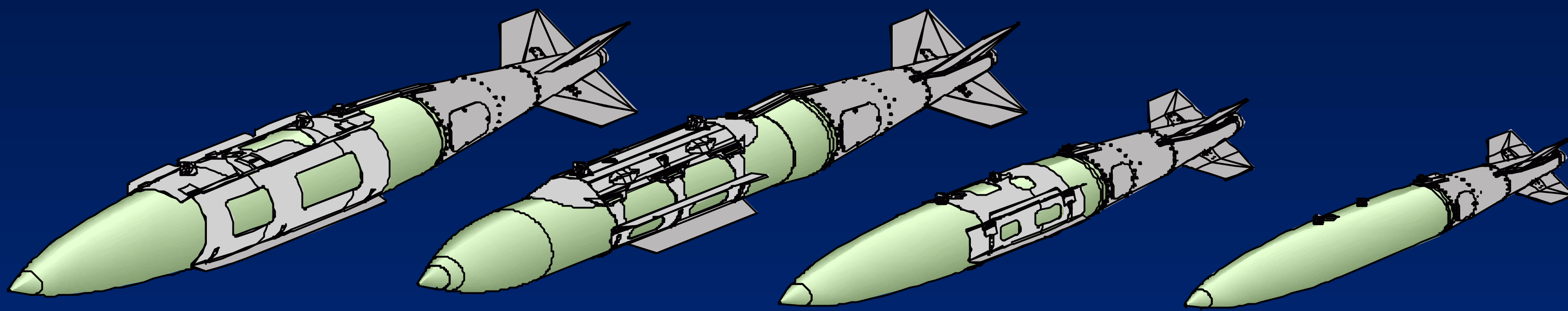
GBU/EGBU-24/27 MISSILE SYSTEM DESCRIPTION

- **Laser Guided Munition Designed for Horizontal and Vertical, Hardened and Deeply Buried Targets**
  - **Laser Designator (Aircraft or Ground)**
  - **Laser Guided MK 84 or BLU-109A/B 2000 Lb. Warhead**
- **Used on Heavily Reinforce Concrete Bunkers, SAM Sites, Etc...**
- **Integrated on the F-117, F-15, F-16, Navy F-14 & F-18**
- **Improvement Program**
  - **Autonomous INS/GPS Laser Guided Provides Adverse Weather Capability**

GBU/EGBU-28 MISSILE SYSTEM DESCRIPTION

- Laser Guided Munition Designed for Super Hardened and Deeply Buried Targets
  - Laser Designator (Aircraft or Ground)
  - WGU 36A/B Laser Guidance Unit
  - BLU-113A/B Penetrator Warhead (5000 LB)
- Developed in 34 days during Operation DESERT STORM
- Integrated on the F-15E Strike Eagle
  - On Going Integration on the B-2
- Improvement Program
  - Examining Improved Penetration
  - Autonomous INS/GPS Adverse Weather Capability
  - Hard Target Smart Fuze

Joint Direct Attack Munition (JDAM) System Description



Mk-84 BLU-109 Mk-83, BLU-110 Mk-82

- Joint Air Force/navy Program to Develop Affordable, Adverse Weather, & Accurate Guidance Kit for 1000 and 2000 Pound Bombs… Eliminate Higher Cost, Limited Utility Interim Weapons
- INS/GPS Guidance Kit Attached to the Bomb Useing Controlled Tail Fin Movements to Direct Bomb to Target
- Fuzes: FMU-139, FMU-143, FMU-152 & DSU-33
- Allows US Forces Precision Engagement in All Flyable Weather
- Lethal...Multiple Kills Per Pass + Fire and Forget
- Interoperable…Bmbers, Fighters, Carrier, Bare Base
  – B-2, B-52, B-1, FA-18, AV-8B, F-22, F-117, F-16, F-15, JSF
- Affordable - Extremely High Capability to Cost Ratio

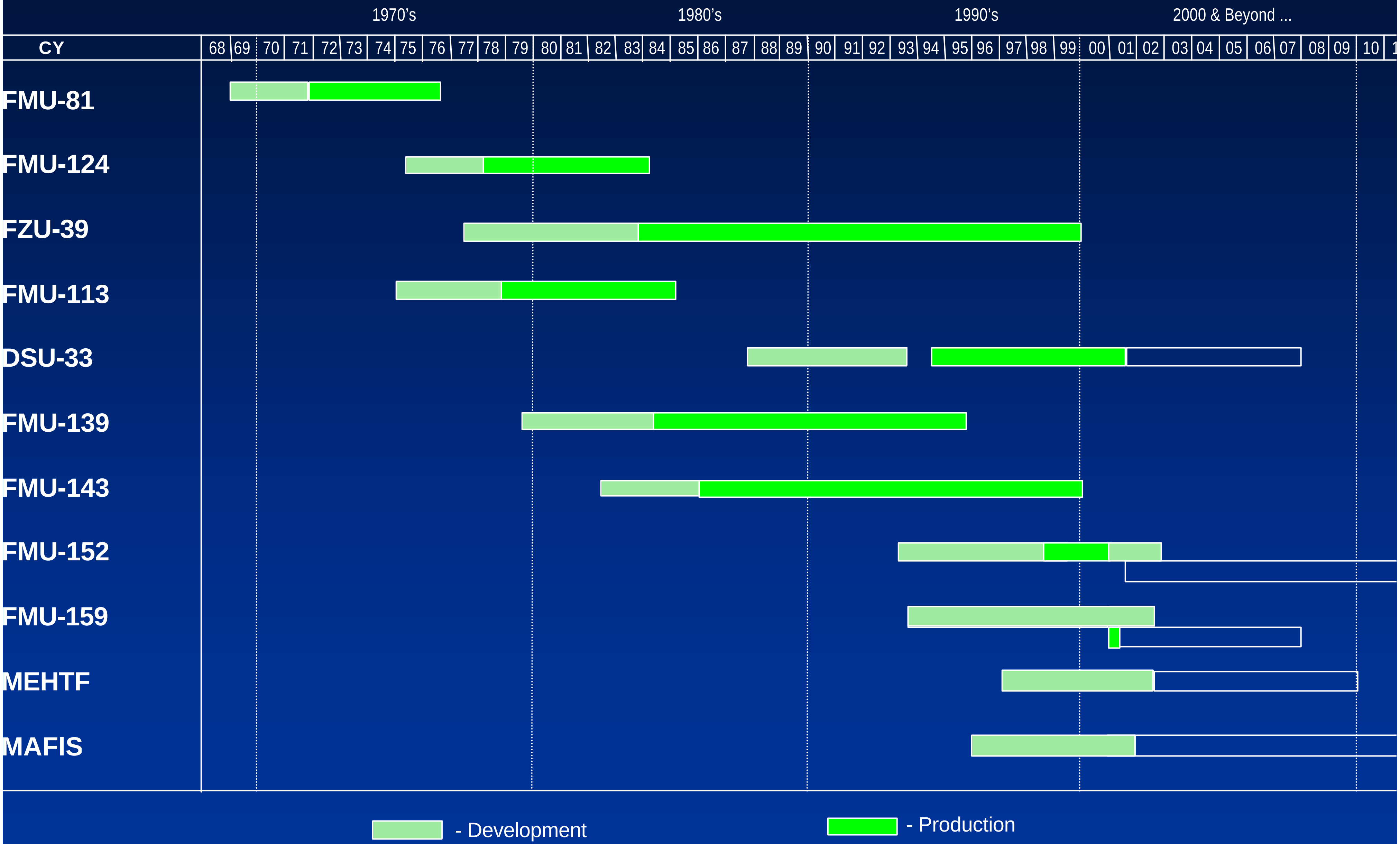
BLAST FRAGMENTATION/PENETRATOR COMBINED/DESIGNS

- **AGM-158 Joint Air-to-Surface Standoff Munition (JASSM)**
- **A Joint Air Force and Navy Program to Provide an Autonomous, Medium Range, Conventional, Air-to-Surface, Precision Missile Able to Strike Highl Defended, High Value Targets**
  - **WDU-42/B (1000 Lb..) Warhead Provides Penetration, Blast & Fragmentation Kill Mechanism Against all Designated JASSM Targets**
  - **INS/GPS Mid-Course Guidance**
  - **I2R Seeker**
  - **Adverse Weather Capability**
  - **Fuze: FMU-156**
- **For Integration on F-16, B-52, B-1B, B-2, F/A-18**
- **15 Year Bumper-to-Bumper Warranty**

FUZE/WEAPON COMPATIBILITY

Weapon System	FMU 143	FMU 124	FMU 152	JUF	DSU 33	FMU 159	FMU 139	FMU 156	MEHTF	MAFIS	FMU 155
Mk 80 Series			X		X		X		O		
BLU-109/113	X		X			X			O		
JDAM	X		X		X	O	X		O		
GBU-15/AGM-130	X	X	X								
GBU-24/27	X		X			X	X		O		
JASSM								X			
GBU-28/37	X		X			X			O		
AGM-142	X	X									
AGM-86D						X					
SDB			TBD			TBD			TBD		
AUP						X					
TTPV						X					
JSOW Unitary				X						X	
SLAM/SLAM ER											X

FUZES/SENSORS SCHEDULE HISTORY



Inventory Fuzes

Production/EMD Fuzes

USAF FUZE INVENTORY
UNGUIDED CLUSTERS

Status March 2001

Function	Type	Quantity	Weapon	Remarks
Time	MK-339	81K	M129E1	Leaflets
Time or Proximity	TMD Fuze/ FZU-39	132K	CBU-87/ 89/97	

USAF FUZE INVENTORY
GUIDED BOMBS

Status as of March 2001

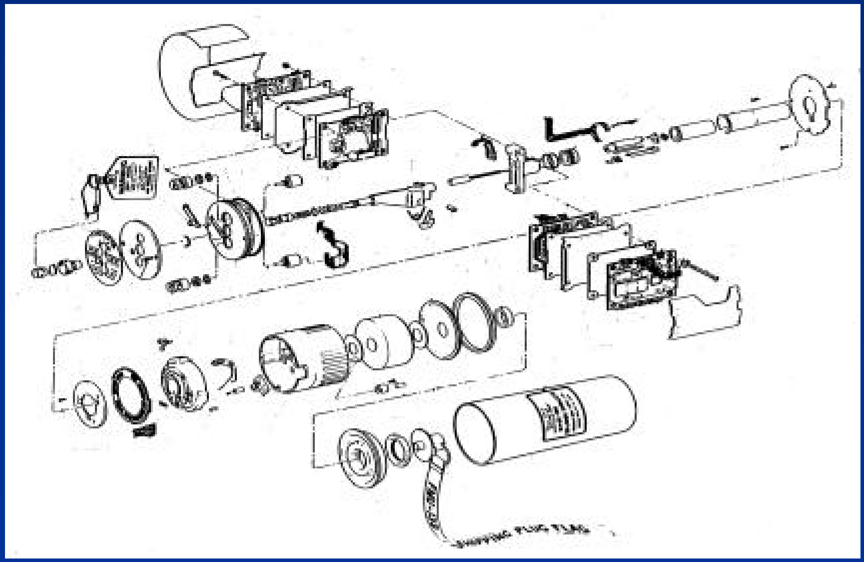
Function	Type	Quantity	Weapon	Remarks
Impact or Impact Delay (Optional)	FMU-81/B	37K	GBU-10/12 (LGB) MK-82, MK-84	
	FMU-124	2.5K	GBU-15, AGM-130, AGM-142, MK-84	
	FMU-139A/B	244K	GBU-24, AGM-65	Replaces FMU-81/B
	FMU-143 B/B	11K	GBU-10/24/27, GBU-15, AGM-130, AGM-142, BLU-109/B	
	FMU-143 F/B,	112	GBU-28	
	G/B	157		
	H/B	73		

FUZE INVENTORY
GENERAL PURPOSE BOMBS

Status as of March 2000

Function	Type	Quantity	Weapon	Remarks
Time	M-904	824K	No Hi Drag	
	M-905	1.1M	No Hi Drag	
	FMU-54A/B	24K	No Hi Drag	
	FMU-54/B	8K		
	FMU-139 A/B	244K		
Proximity	FMU-113	34.6K	No Hi Drag	
	DSU-33A/B	5010		
	DSU-33B/B	2447		(5635 in transit/Prod)

FMU-139B/B FUZE PRODUCT DESCRIPTION



- Electronic impact/impact-delay fuzing system designed for use with general purpose high-explosive bombs
- Delivered with FZU-48/B initiator, power cable (attached) and closure ring
- Provides multiple fuzing options for:
  – Tail fuzing only
  – Nose fuzing only, and
  – Nose and tail fuzing

FMU-139B/B FUZE

- FMU-139B/B fuze is interoperable with all FMU-139A/B applications
- Compatible with laser guided bombs and with low and high speed drag air foil groups
- Compatible with DSU-33A/B and DSU-33B/B proximity sensor
- FMU-139 currently in use with MK80 series Joint Direct Attack Munition (JDAM)
- Being Replaced by FMU-152 Joint Programmable Fuze

FMU-143 A-H/B FUZE DESCRIPTION

- Impact Delay Fuze for Penetrating Warheads (Single 0.060 Sec. Delay)
- Interface - BLU-109, BLU-113, AGM-142 I-800
- Power/safety - FZU-32B/B Bomb Fuze Initiator, GBU-15/AGM-130 Battery
- Used On -GBU-10, 24, 27, 28, 31, AGM-142, and AGM-130, (With BLU-109 or BLU-113 Warheads)
- Being Replaced By FMU-152, JPF
- Manufacturer - Dayron Inc., Orlando FL.

FMU-143 A-H/B FUZE SYSTEM

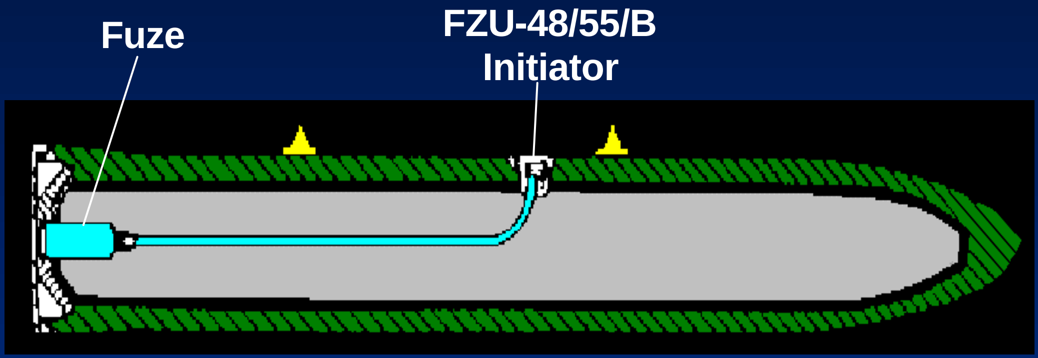
Configuration	User	Modification
FMU-143B/B and FMU-143B(D-2)/B	AF, FMS, JDAM	Basic - 60ms Delay, 5.5 or 12 sec Arm Time
FMU-143D/B and FMU-143D(D-2)/B	AGM-142	21 Sec Arm Time
FMU-143E/B and FMU-143(D-1)/B	Navy	PBXN-7 Booster/Lead
FMU-143F/B	GBU-28	30ms Delay/21 Sec Arm
FMU-143G/B	GBU-28	60ms Delay Same
FMU-143H/B	GBU-28	120ms Delay Same

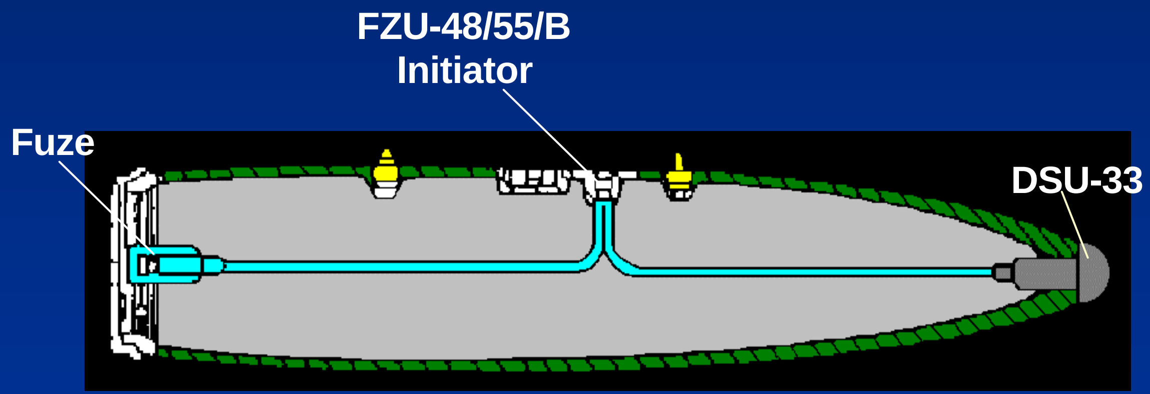
ADVANCED FUZES AND SENSORS

Joint Programmable Fuze

Hard Target Smart Fuze

DSU-33B/B Proximity Sensor





JOINT PROGRAMMABLE FUZE (JPF)

FMU-152/B

FMU-152/B JPF SYSTEM DESCRIPTION

- Single Fuze Compatible With Mk82, Mk83, Mk 84, BLU-109, BLU-113 for Use in AGM-130, GBU-10/12/15/16/24/27/28 and All JDAM Variants
- Can Be Used in Current FMU-139 and FMU-143 Applications
- Cockpit Selectable Arm/delay Times
  - Instantaneous to 24 Hours
- Multi-function Capability
  - Hard Target Penetrator Weapons
  - Blast Fragmentation
  - Backward Compatibility With Current Weapons

FMU-152/B JPF REQUIREMENTS

Performance	Threshold Parameters
Weapon Interface	AGM-130, GBU-10/12/15/16/24/27/28, JDAM
Warhead Interface	MK-82/83/84, BLU-109/113
Low Drag Arm Time (Sec)	4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 10.0, 14.0, 21.0, 25.0
High Drag Arm Time (Sec)	2.0, 2.6, 3.0, 3.5, 4.0, 5.0
Impact Delay Times	0, 5, 15, 25, 35, 45, 60, 90, 180, 240 Msecs 15, 30, 45, 60 Min 4, 8, 12, 16, 20, 24 Hrs
Reliability	0.98
Service Life	10 Years
Shelf Life	20 Years

Note: Yellow Denotes Fuze Panel Switch settings

FMU-152/B JPF PROGRAM OVERVIEW

- Program Phase: Production
- Contractor: Dayron
- Current Unit Price : $2.167K
- Quantities: 62,000 (AF)/25,496 (Navy)
- Joint Service: Air Force (Lead)/Navy
- First Article Acceptance Testing - Summer 01
- JDAM High Altitude Low Airspeed Release Challenges
  - FZU- 55 Improvements - LRIP 2 and Beyond
  - Additional FMU-152 Improvements - LRIP 4 and Beyond

HARD TARGET SMART FUZE (HTSF)

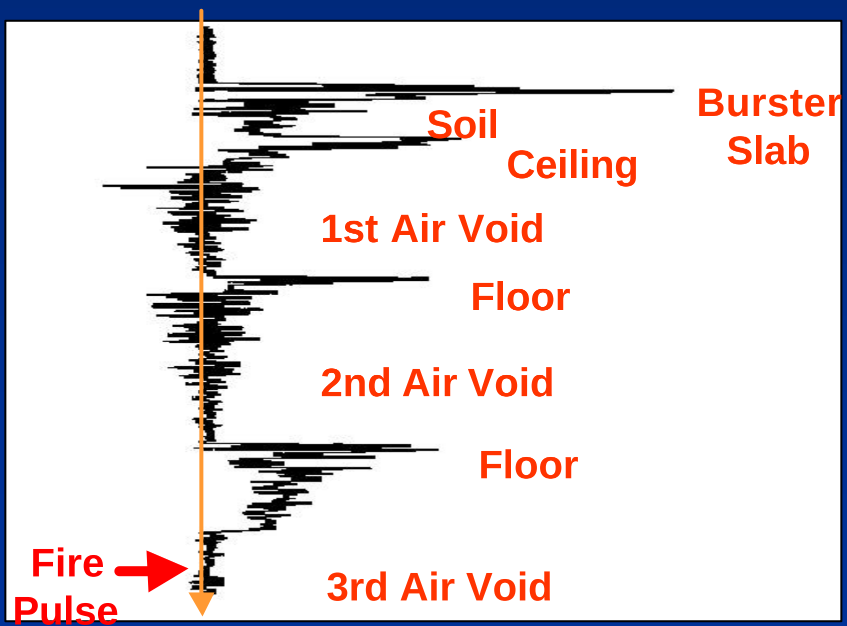
FMU-159/B

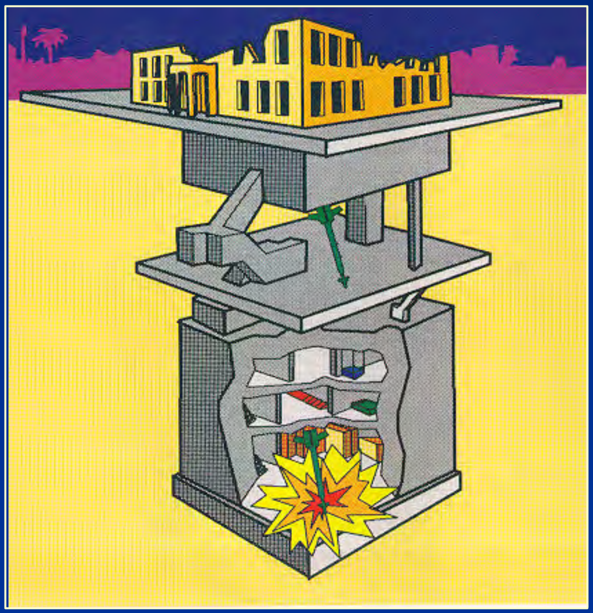
FMU-159/B HARD TARGET SMART FUZE PROGRAM OVERVIEW

- **Program Phase: EMD**
- **Contractor: Alliant Techsystems**
- **Value: EMD $18.5M, Prod $34M**
- **Quantities: 500+ (AF) / 500+ (Navy)**
- **Joint Service: Air Force (Lead)/Navy**
- **“Smart” Fuze for Penetrator Weapons**
- **Allows Defeat of High Value Hard Targets**

VOID SENSING, LAYER COUNTING, DEPTH OF BURIAL CAPABILITIES

- Contains a precision accelerometer and microcontroller
- Senses voids and layers, computes depth of burial
- Detonates warhead at user programmed point within target
- Programmable modes
  - Void or Layer Count, and Depth of Burial
  - Function Distance/Time after Void/Layer event
  - Redundant Backup Timer 0 to 255ms





FMU-159/B HARD TARGET SMART FUZE EMPLOYMENT PLATFORMS & WEAPONS

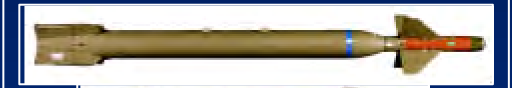
B-52H

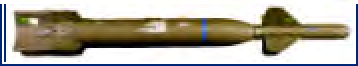
AGM-86D CALCM Penetrator

B-2A

GBU-37, EGBU-28

F-15E





GBU-28, EGBU-28, GBU-24/27

F-117A

GBU-27

F/A-18 **F-14**

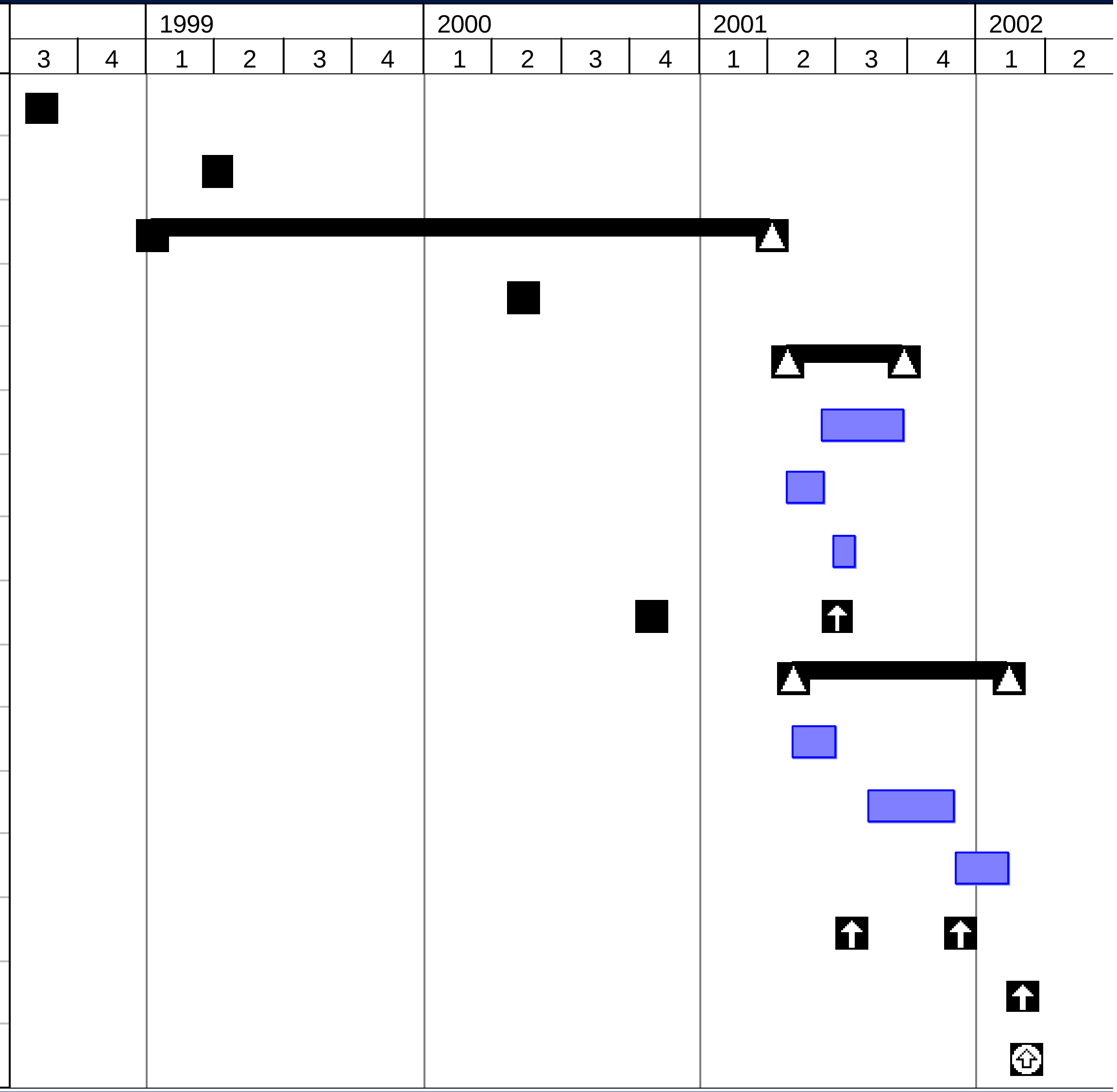
GBU-24G/B
(BLU-116)

Missile Cruisers & Destroyers

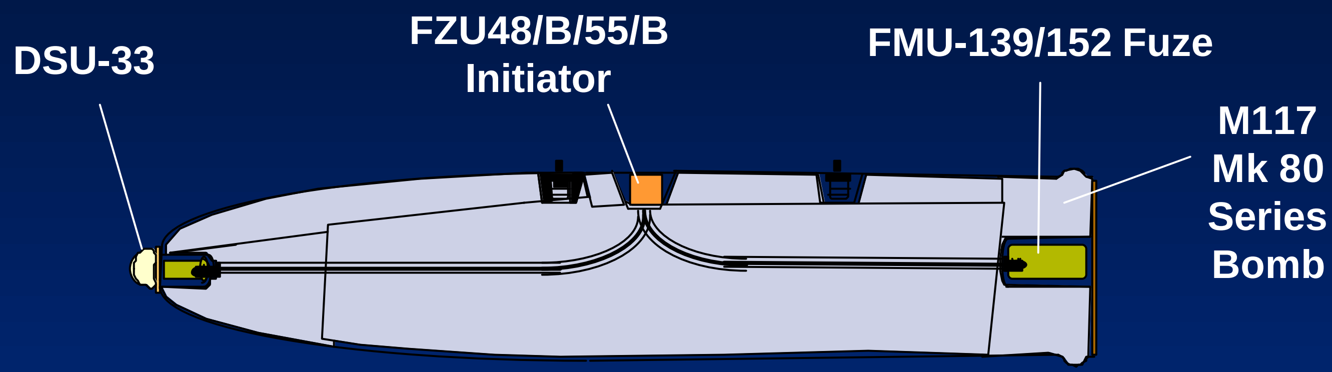
BGM-109H
Tactical Tomahawk Penetrator

FMU-159/B HARD TARGET SMART FUZE SCHEDULE SUMMARY MAR 01

Task Name	Start	Finish
Contract Award	8/11/98	8/11/98
Prelim Design Review	3/31/99	4/1/99
Design/Development	1/4/99	4/5/01
Critical Design Review	5/10/00	5/11/00
Contractor Test & Eval	**4/23/01**	**9/26/01**
Qual Tests	6/7/01	9/26/01
Cannon Tests	4/23/01	6/13/01
Sled Tests	6/25/01	7/25/01
PPO1 Exercise / Begin Build	10/26/00	6/29/01
DT&E/OT	**5/1/01**	**2/12/02**
FZU-60 Flt Test	5/1/01	6/29/01
Sled Testing	8/9/01	12/4/01
Flt Test	12/5/01	2/12/02
PPO2 Exercise / Begin Build	7/17/01	12/11/01
NNMSB / WSESRB Final	2/27/02	2/27/02
PCA / PRR MSIII	3/6/02	3/6/02



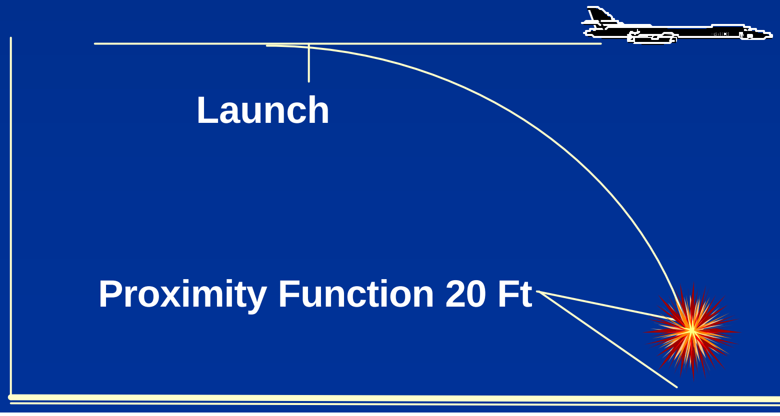
DSU-33 PROXIMITY SENSOR



Air Force Configured System

DSU-33 B/B PROXIMITY SENSOR

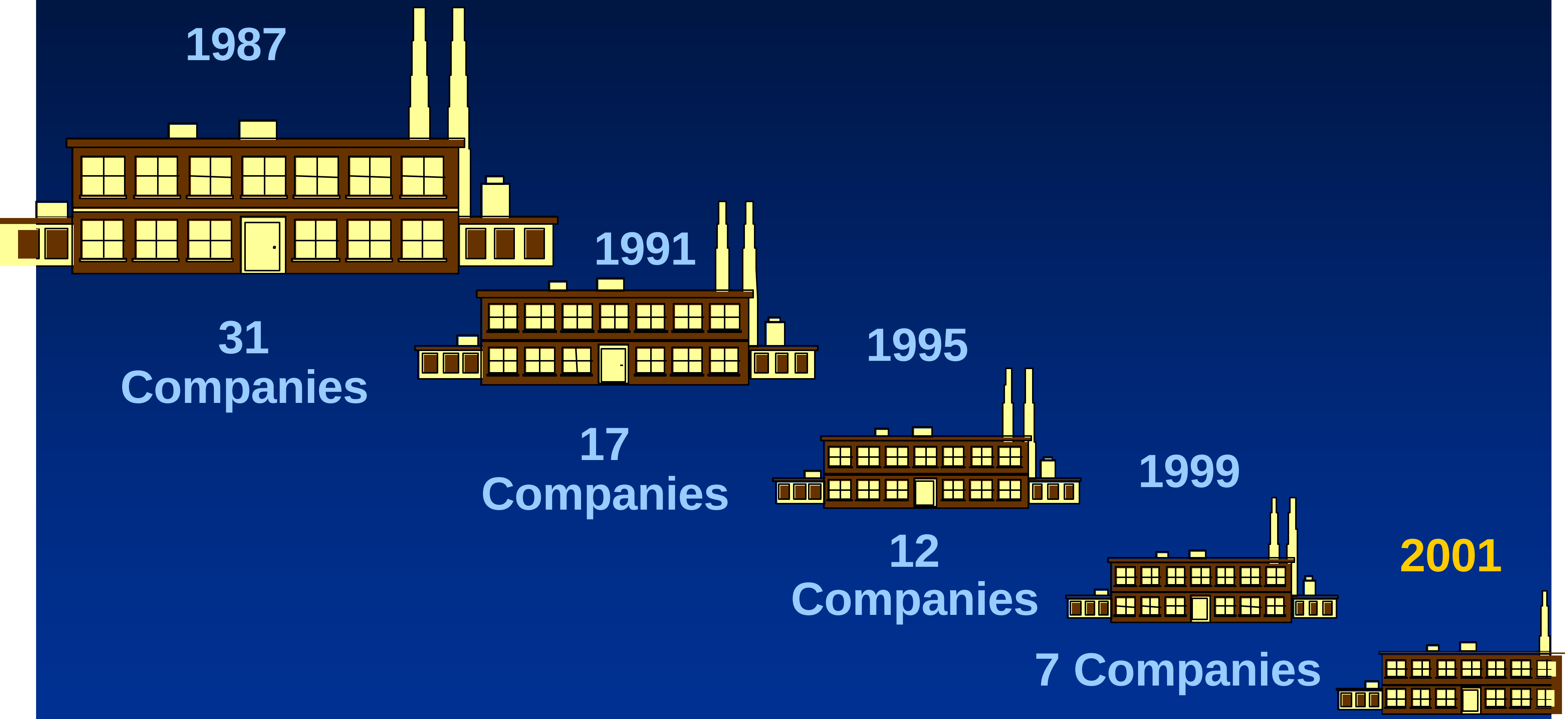
- Current Production With Alliant Techsystems
- Air Burst Proximity Fuzing for Mk80 Series/m117 General Purpose Bombs and JDAM Variants
- Continuous Wave Doppler Radar Provides Fire Pulse Signal to the FMU-139 and FMU-152/B
  - Height of Burst (HOB): 20 Feet
  - Over All Water and Land Surface Conditions
- Attacks Surface Level Targets
- 9,996 Units Deliverd Thru Mar 2001 (AF & Navy)
  - 3501 Remaining



CHALLENGES FOR TODAY'S AND TOMORROW'S FUZE PROGRAMS

- **Shrinking Industrial Base**
- **Increasing Complexity & Cost**
- **Diminishing Verification Opportunities**
- **Aging Inventory**
- **Increasing Expectations**
- **Aircraft & Missile Interface Challenges**

SHRINKING CONVENTIONAL FUZE INDUSTRIAL BASE



7 US & Internatio
Consortiums

*** Source: Army Fuze Management Office**

JOCG Fuze Subgroup Meeting 11 Aug 99

SHRINKING INDUSTRIAL BASE
(CONT)

- Funding Requirements in Support of Current Operations and Declining Acquisition Budgets Negatively Impact Development and Production Efforts
  - Fewer New Starts
  - Smaller Production Quantities Spread Over Longer Periods
- Increasing Reliance on Electronic Fuzing Reduces the Need for Older Mechanical Fuzes
  - Requires Higher Level of Technical Ability
  - Fuze Contractors Must Adapt or Face Dwindling Business
- Opportunity - DSU-33 Production Competition for FY 02-07 Requirements

SHRINKING INDUSTRIAL BASE
(CONT)

- **Erosion of Essential Human Resources**
  - **Technical Expertise is there, but in insufficient numbers**
  - **Lack of Technical Breadth/Experience impacts Problem Solving**
    - **No Technical Surge Capability**
    - **Failure Analysis Slow**
    - **Limited Understanding of Fuze Design and Operation**
  - **Government In-house Expertise is Retiring (Vietnam/Post-Vietnam era)**
  - **Recruiting and Retention is a major Challenge in this Market Sector**
- **JOCG Fuze Subgroup to Brief JOCG in Sep 01 on Industrial Base Status**

INCREASING COMPLEXITY AND COST

- Single Fuze Combining the Function of Several Fuzes
  - e.g., FMU-152/B JPF Is Both a Blast-frag and Penetrator Fuze
- Designs Take Advantage of Modern Electronics and Computer Technology
  - More Versatile, More Precise
  - More Complex Sensing and Logic Functions
- Mission Planning Becomes More Detailed and Critical
- FMU-159/B Hard Target Smart Fuze
  - Void/layer Count, Timer, Back-up Timer
  - Programmable With 22 Settings on the Ground, 11 From the Cockpit
- Multi-event Hard Target Fuze
  - Thin Layer Detection, in Addition to Voids/timers
  - Cockpit Programmable
  - Fuze Information for Bomb Damage Information

DIMINISHING VERIFICATION OPPORTUNITIES

- **Advanced Fuze Verification Programs Are Very Expensive and Necessitate Limited Test Programs**
  - **Targets to Verify Fuze Performance Are Large, Multi-floor Structures**
- **FMU-152/B - 5 Sled Tests, 193 Flight Tests (DT/OT)**
- **FMU-157/B (ACTD) - 23 Sled Tests, 32 Flight Tests**
- **FMU-159/B - 18 Sled Tests, 11 DT Flight Tests, 2 OT Flight Tests**
  - **No AF GBU OT&E Because of High Cost and Limited AFOTEC Budget**
  - **Original AF GBU OT&E Planned for 13 Flights Using 19 Weapons**

AGING INVENTORY

- Much of Fuze Inventory Is Approaching End of Expected Life
  - Historically at 20 Years Reliability Problems Begin
  - AF Generally Accepts Older Fuzes at 90% Reliability With 90% Confidence
    - After That Either Double Fuze or Put 2 Weapons on Target
- Reliability of Older Fuzes Is a Current Issue
  - FMU-124B/B Surveillance Testing Failures (6 out of 72)
- Lack of Comprehensive Replenishment Plan
  - Insufficient Budgets to Efficiently Replace Older Inventory
- Refurbish or Replace?
  - FMU-139
    - AF - Replace With FMU-152 Over Time
    - Navy - Rebooster Challenges

INCREASING EXPECTATIONS

- **Warfighters Expect “First Time - Every Time” Performance**
  - **Objectives of 98% Reliability**
- **“Smart” Communications**
  - **Cockpit Programming Is Now Standard**
  - **Bomb Damage Information Is Desired for the Future**
- **Fuze Must Perform in Ever-expanding Performance Envelopes**
- **Fuze Design Capturing System Responsibilities**
  - **High Altitude, Low Airspeed Release Conditions**
  - **Navy Fuze Function Control Set (FFCS)**
- **Safety Certification of Electronic Fuzes Is More Difficult Than Mechanical Fuzes**
  - **Old Paradigms Don’t Apply**

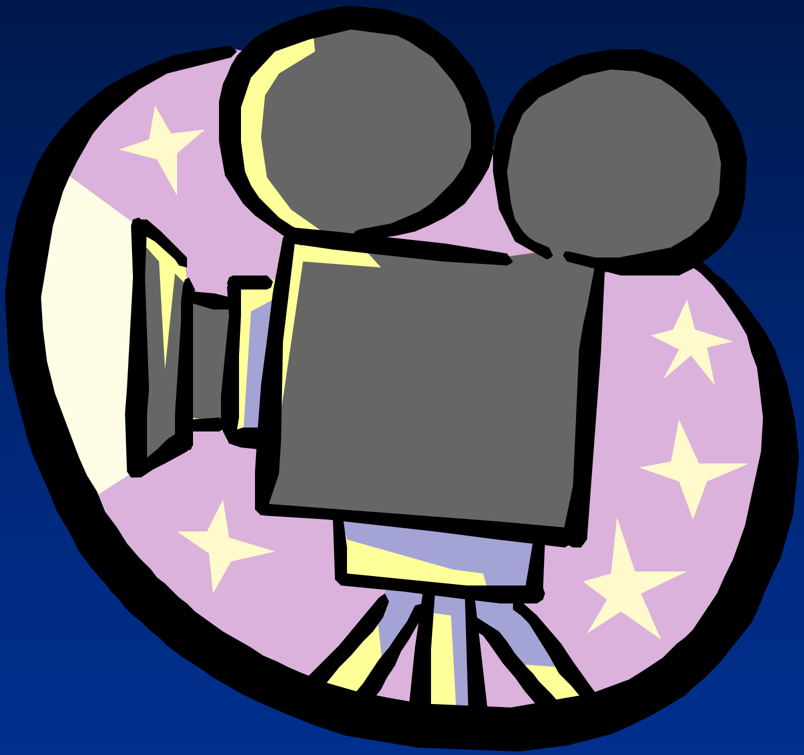
AIRCRAFT AND MISSILE INTERFACE CHALLENGES

- Navy Fuze Function Control Set
  - Anomalies Yielding Low Reliability With Electrically Fuzed Bombs (E.G., F/A-18 - 88%)
- High Altitude - Low Airspeed Release
  - Initiator Turbine Starved for Air Causes Arming Problems
  - JDAM Roll Stabilized Flight and AoA Compounds the Situation
- Long Term Storage Reliability and Safety Requirements While Installed in Cruise Missiles
- Allied Interoperability
  - Fuze Well Size
  - Fuze Power Source
  - Communications Interface

POSITIVE RESULTS

- Significantly Increased Capabilities
  - Performance Characteristics
    - Void/layer Detection
    - Increased Survivability
    - Cockpit Programmability
  - Very High Reliability Requirements
    - HTSF and JPF - .98 (Mission),.95 (Storage)
    - MEHTF - .99 (Mission and Storage) Goal
- Joint Programs Are the Norm
  - DSU-33, JPF, HTSF
- Growing Realization of Critical Nature of Fuzing
  - Fuzing Is Small Diameter Bomb's (SDB) #1 Risk
  - HTSF Is on CALCM 86-D Critical Path
  - Major Growth Area for JDAM

Video

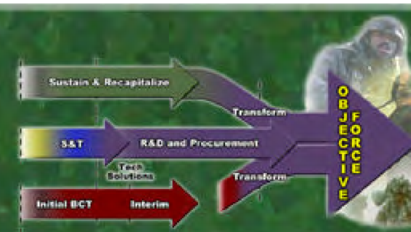


Any Questions?

45th Annual NDIA FUZE Conference
17-18 April 2001

PEO Tactical Missiles

COL Jody Maxwell, Director
System Integration & Operations



PEO TACTICAL MISSILES OVERVIEW

PROGRAM EXECUTIVE OFFICER TACTICAL MISSILES

MISSION

Provide the American Soldier with the finest, combat effective, tactical missile systems in the world in a timely and cost-effective manner while fully supporting The Army's transformation.

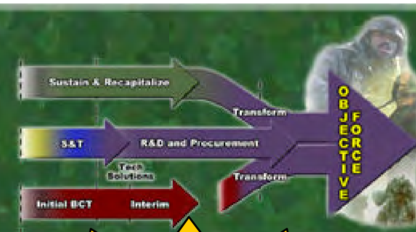
VISION

A world-class government / industry team that gives the American soldier an unparalleled, overmatch tactical missile capability that allows our Army to fight and win on the 21st century battlefield with minimal casualites in the shortest time possible.

GOALS

- Excel beyond all others in fielding the best tactical missile systems in the world.
- Effectively team with industry.
- Build the Army Acquisition Corps of the future.
- Mature & weaponize critical technologies for the Objecitve Force.
- Reduce the Life Cycle Cost & in-theater logistics footprint of our missile systems.

PEO TACTICAL MISSILES



FY00 MANPOWER REQUIREMENTS

	CORE	MATRIX
CIVILIAN	281	611
MILITARY	37	10
CONTRACTOR	76	502
TOTAL	394	1123

PEO TACTICAL MISSILES

DEPUTY PEO
PRINCIPAL STAFF
EUROPEAN REP

AVIATION

PM AVIATION ROCKETS & MISSILES

- LONGBOW HELLFIRE ACAT IC
- LASER HELLFIRE
- HYDRA 70
- MODERNIZED HELLFIRE
- APKWS

FIRE SUPPORT

PM ATACMS - BAT

- ATACMS / BAT ACAT ID
  - BAT
  - BAT P3I
  - BLK II
- ATACMS / APAM ACAT IC
  - BLK I

PM MLRS

- M270A1 ACAT1C
  - IFCS ACAT III
  - ILMS ACAT III
- ER-MLRS ACAT III
- GMLRS ACAT III
- HIMARS ACTD

MANEUVER

PM CCAWS

TOW FIRE & FORGET
IBAS ACAT II
ITAS
T2SS

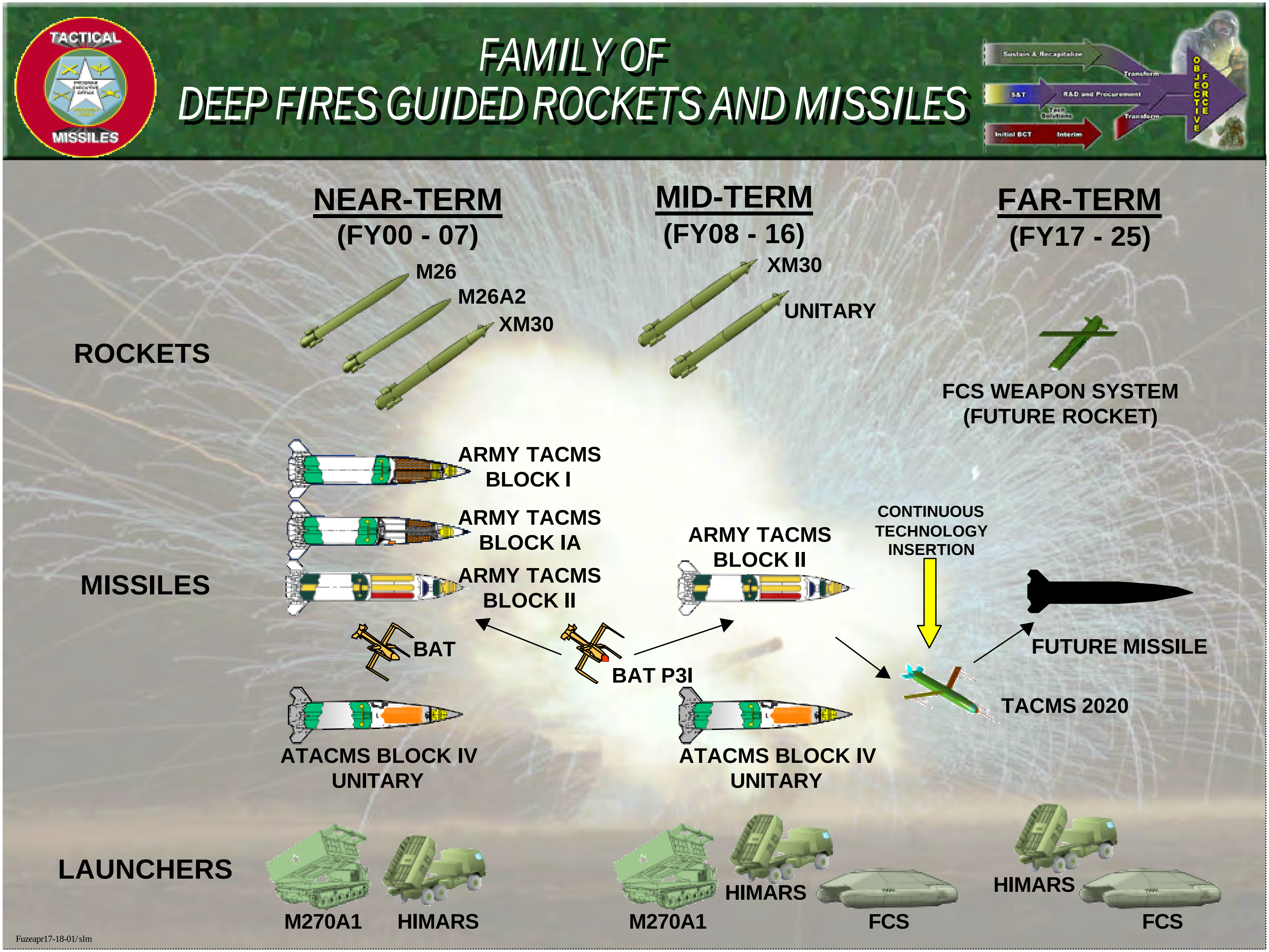
PM JAVELIN

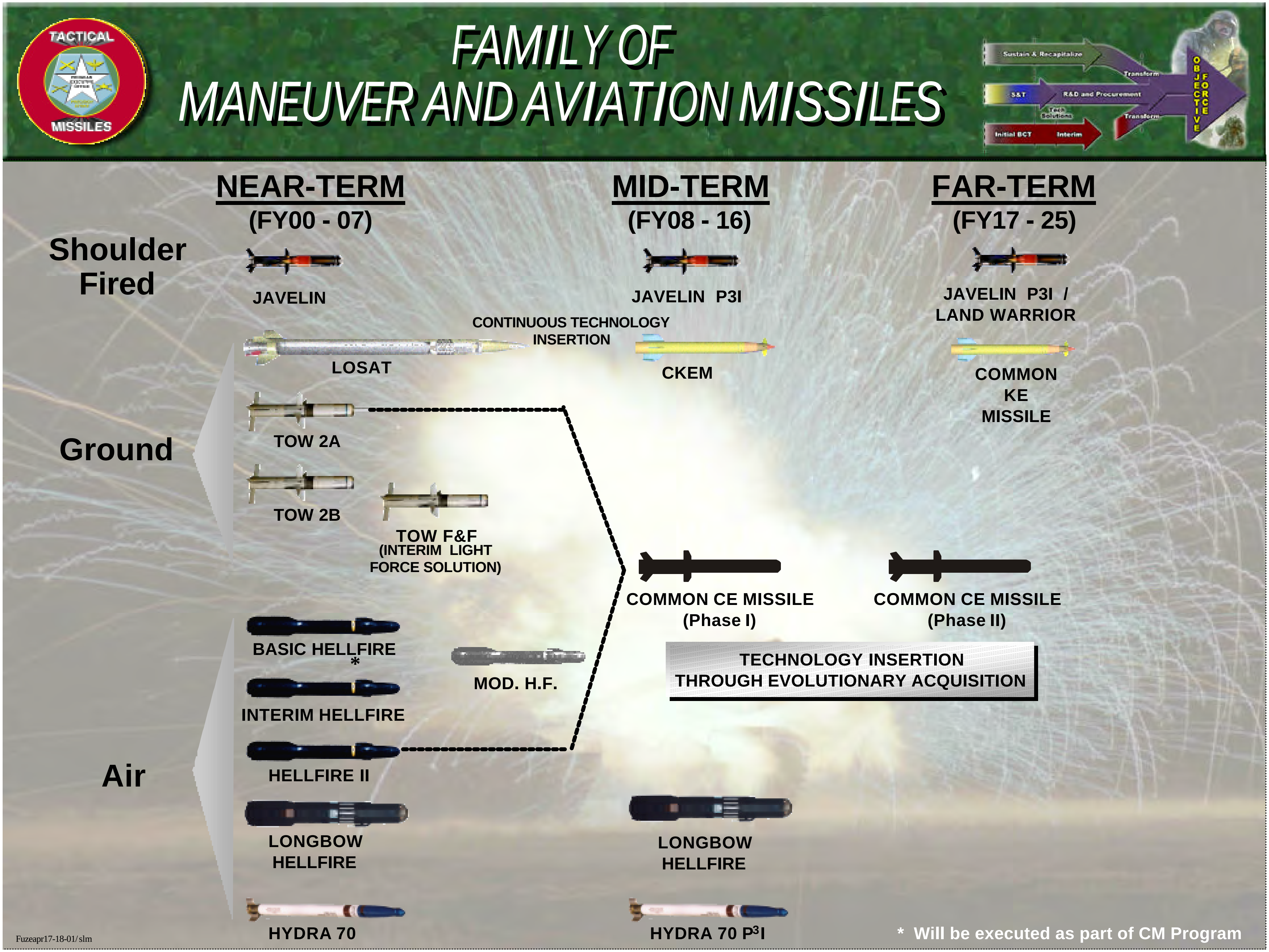
JAVELIN ACAT IC

PM KINETIC ENERGY MISSILES

LOSAT ACTD+

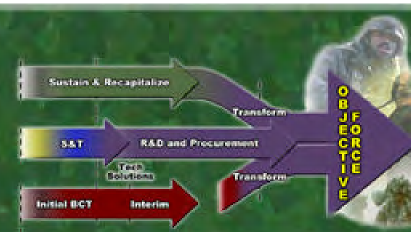
Fuzeapr17-18-01/slm


TACTICAL
MISSILES
FAMILY OF
DEEP FIRES GUIDED ROCKETS AND MISSILES
Sustain & Recapitalize
Transform
S&T
R&D and Procurement
Tech Solutions
Initial BCT
Interim
Transform
OBJECTIVE FORCE
NEAR-TERM
(FY00 - 07)
MID-TERM
(FY08 - 16)
FAR-TERM
(FY17 - 25)
ROCKETS
M26
M26A2
XM30
XM30
UNITARY
FCS WEAPON SYSTEM
(FUTURE ROCKET)
MISSILES
ARMY TACMS
BLOCK I
ARMY TACMS
BLOCK IA
ARMY TACMS
BLOCK II
ARMY TACMS
BLOCK II
CONTINUOUS
TECHNOLOGY
INSERTION
BAT
BAT P3I
FUTURE MISSILE
TACMS 2020
ATACMS BLOCK IV
UNITARY
ATACMS BLOCK IV
UNITARY
LAUNCHERS
M270A1
HIMARS
M270A1
HIMARS
FCS
HIMARS
FCS
Fuzeapr17-18-01/slm


TACTICAL
MISSILES
FAMILY OF
MANEUVER AND AVIATION MISSILES
Sustain & Recapitalize
Transform
S&T
R&D and Procurement
Tech Solutions
Transform
Initial BCT
Interim
OBJECTIVE FORCE
NEAR-TERM
(FY00 - 07)
MID-TERM
(FY08 - 16)
FAR-TERM
(FY17 - 25)
Shoulder Fired
JAVELIN
JAVELIN P3I
JAVELIN P3I / LAND WARRIOR
CONTINUOUS TECHNOLOGY INSERTION
LOSAT
CKEM
COMMON KE MISSILE
Ground
TOW 2A
TOW 2B
TOW F&F
(INTERIM LIGHT FORCE SOLUTION)
COMMON CE MISSILE (Phase I)
COMMON CE MISSILE (Phase II)
BASIC HELLFIRE
*
MOD. H.F.
TECHNOLOGY INSERTION THROUGH EVOLUTIONARY ACQUISITION
INTERIM HELLFIRE
Air
HELLFIRE II
LONGBOW HELLFIRE
LONGBOW HELLFIRE
HYDRA 70
HYDRA 70 P3I
* Will be executed as part of CM Program
Fuzeapr17-18-01/slm

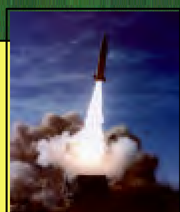
FIELDING TO THE FORCE

TACTICAL MISSILES



FUE: LAST FOUR YEARS


JAVELIN - JUL 96


BLK 1A - FEB 98


IPDS LAUNCHER - FEB 98


HIMARS (PROTOTYPES) FEB 98

LONGBOW - JUL 98



ITAS - SEP 98


ER-MLRS MAR 99

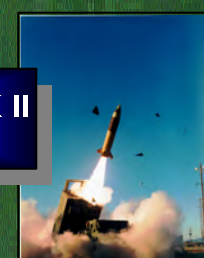
FIELDINGS CONTINUE

NEXT TWO YEARS

IBAS AUG 00

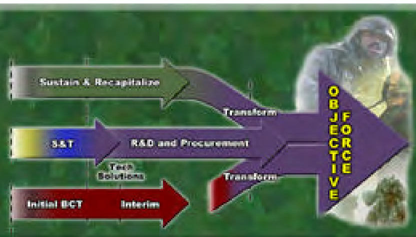


M270A1 UPGRADE SEP 01

ATACMS BLK II SEP 01


OPTEMPO IS INCREASING

Proposed Organization



PEO
Tactical Missiles

PM
Common Missile
- Air Integration
- Ground Integration

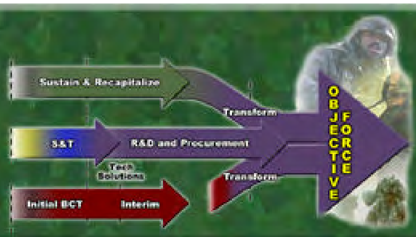
PM
Fire Support Rockets & Missiles
- GMLRS
- P3I BAT
- Future Munitions
- Unitary Munitions
- Launcher

PM
Aviation Rockets & Missiles
- Hydra 70
- Longbow

PM
Kinetic Energy Missile
- LOSAT

PM
Grd Maneuver Missiles
- Javelin
- Tow F&F

THE SITUATION

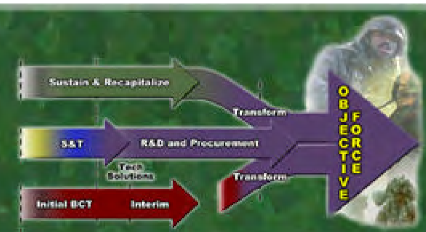


- In 1991 Following Desert Storm a requirement for <1% hazardous duds left on Battlefield was established

- Analysis of proposals indicated SDF as the most feasible option to meet the user requirement

- SDF development contract issued in 1992 with planned incorporation into ER MLRS in 1998

- To date Tactical Missile PEO has expanded approximately $64M for development, testing of HRE, and LRIP for XM 235 SDF

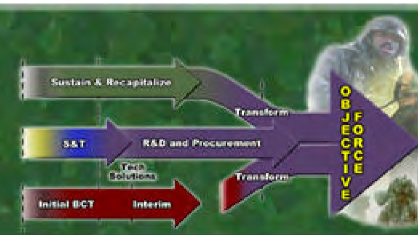


THE RESULTS

- The Production of ER MLRS began in 1996 without a SDF
- FMS cases have been lost and others are jeopardized due to the lack of a SDF
- HRE will not meet required rate
- Proposed HRE recovery plan is high risk
- LRIP contract terminated

Bottom Line: Over ten years and $64M invested in a solution for <1% hazardous duds with no acceptable solution in sight

TECHNOLOGY TRENDS

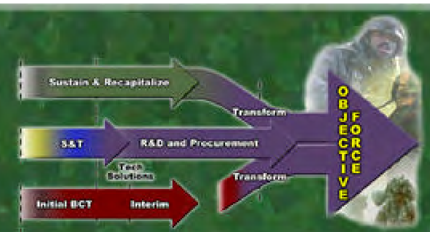


- FIRE AND FORGET TECHNOLOGY
- FOCAL PLANE ARRAY (FPA)
- DUAL MODE / MULTI-MODE SEEKERS
- DEWAR DETECTOR COOLERS (DDC)
- TANDEM WARHEADS
- INERTIAL MEASUREMENT UNITS (IMU)
- GLOBAL POSITIONING SYSTEMS (GPS)
- GLOBAL POSITIONING SYSTEMS GUIDANCE PACKAGE (GGP)
- ELECTRONIC SAFE AND ARM ES&A DEVICES
- ADVANCED SIGNAL PROCESSING

THESE TECHNOLOGY TRENDS BRING TECHNOLOGY CHALLENGES

FUZE TECHNOLOGY DEVELOPMENT MUST KEEP UP WITH ADVANCES IN TECHNOLOGY

PATH FORWARD



- U.S. is committed to lower UXO on the Battlefield

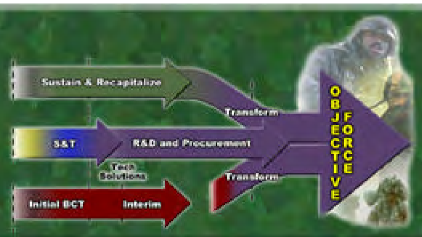
- New DOD Policy issued 10 Jan 2001 stating a desire to field future submunitions with a 99% or higher function rate
  - "Future" submunition weapon is one that will reach MS II after first quarter of FY 2005

- It's clear we can't continue to do business as usual

- Consider other FUZE designs (Improved mechanical, Pyro delays)

- Most promising option is to pursue a Co-operative development of a European SDF that will transfer the qualified design to a US contractor for production

PATH FORWARD



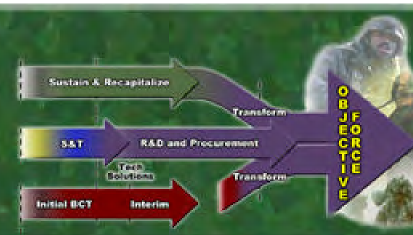
- **Industrial base must define common architecture**

- **Combine performance & environmental requirements for targeted programs**

- **Common module approach**
  - **Flexible hardware building blocks**
  - **Programmable for multiple applications**

- **Common Components**
  - **Configured to adapt to peculiar system interfaces**
  - **Packaged to accommodate worst case scenario**

- **Partitioned for Growth**
  - **Unique functions & interfaces segregated**



CONCLUSION

- **Concern over dirty battlefield is increasing as evidenced by 99% UXO requirements**

- **Quantities and funding for specific weapons systems are decreasing**

- **Fuze industrial base must develop designs that are transportable to other systems. Production facilities must be capable of producing more than one item at high rates**

We simply cannot afford to develop and support new unique pinpoint designs for each system

Naval Air Systems Command Fuzing Overview

Steven E. Fowler
Head, Ordnance Systems Division
Code 478000D
Naval Air Warfare Center, Weapons Division

NAVAL AVIATION SYSTEMS TEAM

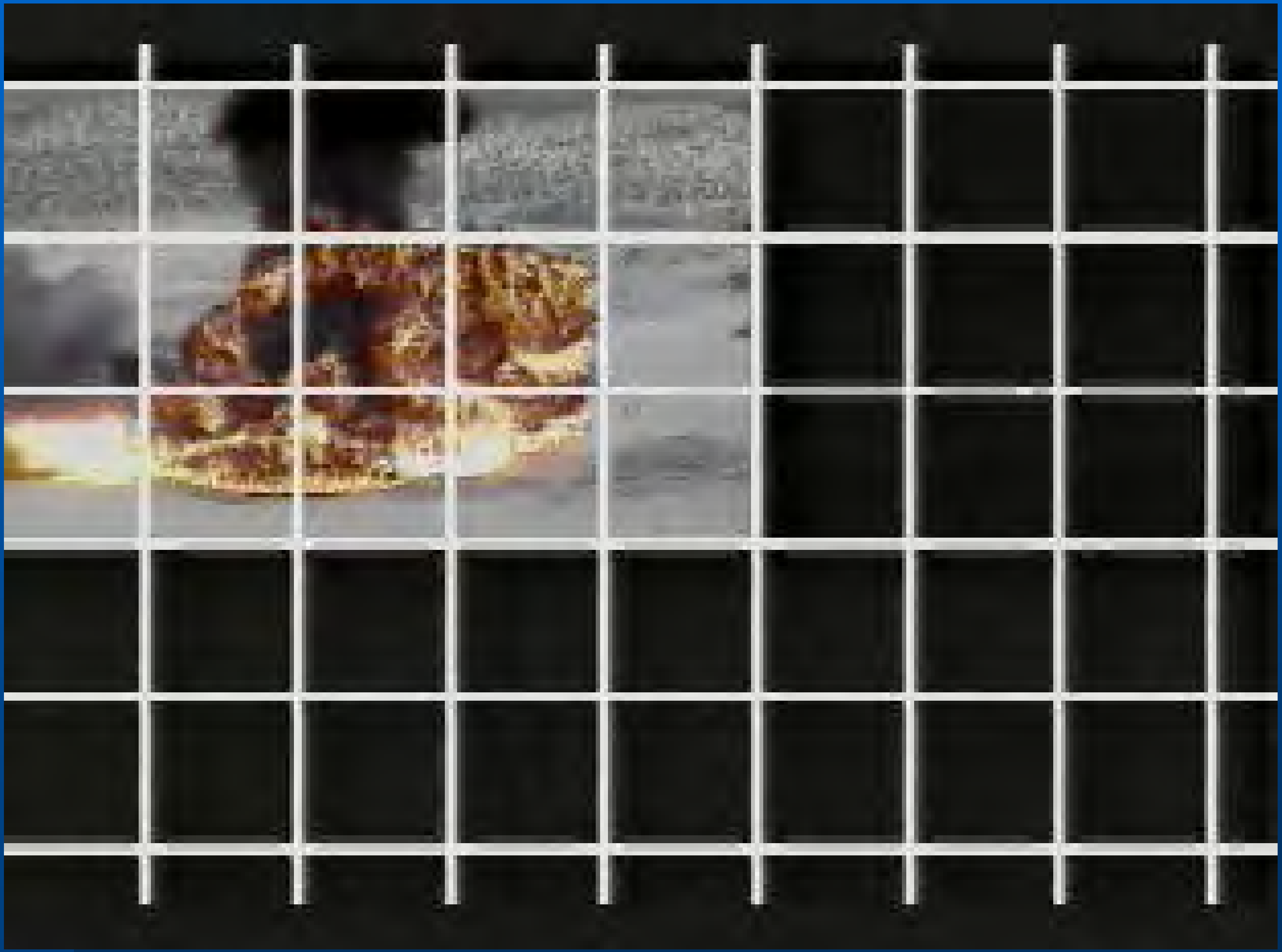
DEPARTMENT OF THE NAVY AIR SYSTEMS COMMAND

NAWC Weapons Division NAVAL AIR WARFARE CENTER

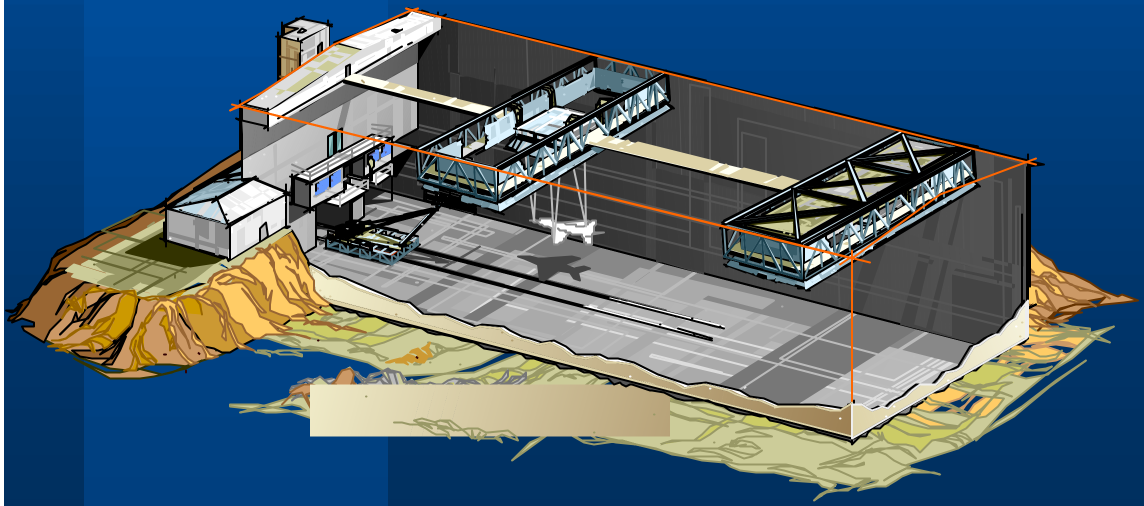
WEAPONS TARGETS DEPARTMENT 4T

Naval Air Warfare Center Weapons Division

A Full-Spectrum Capability



Missile Engagement Simulation Arena



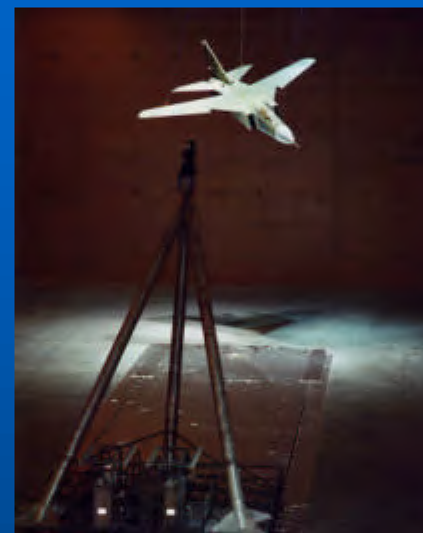
- **Products and Services**
  - **Fuze**
    - **Testing and evaluation**
    - **Consultation on design and testing methodologies**
  - **Diverse Testing operations**
  - **TDD Foreign Military Exploitation**
  - **Field test consultation**
  - **Portable radar signature/ antenna testing**

Length = 405 Ft
Width = 150 Ft
Height = 90 Ft

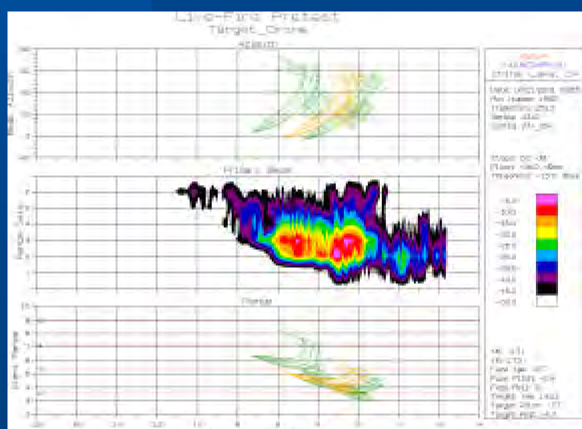
MESA Testing of Full-Scale Aircraft

F-4 Fighter

Fuze Testing Against F-18



Mig-23 Fighter



Example of Fuze Data Results

- **Guidance and Fuze Testing**
  - **Fuze Design and Development**
  - **Fuze optimization**
  - **Platform survivability**
  - **Terminal guidance investigation**

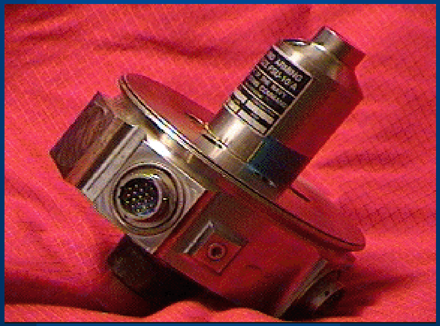
Fuze Systems

Missile S-A Devices

HARM MISSILE FUZE,
FMU-111/B

TOMAHAWK BLK 3 FUZE,
FMU-148/B

SLAM ER, FMU-155/B



PHOENIX MISSILE FUZE,
FSU-10/A

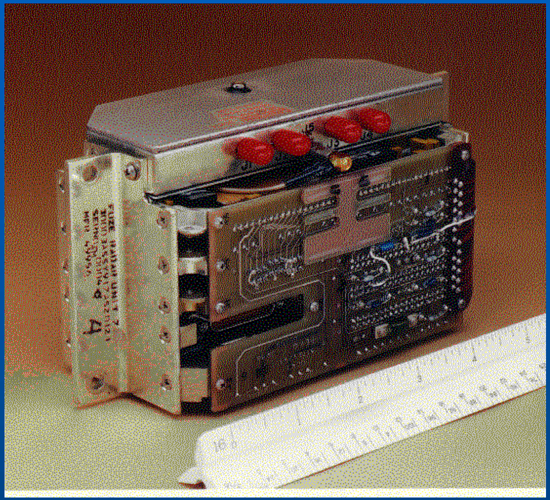
SPARROW MISSILE S-A, MK-33

SIDEWINDER MISSILE FUZE,
MK-13 MOD 2

STANDARD MISSILE
S-A, MK 54 MOD 0

Missile Target Detecting Devices

RAM
MK-20 AOTD



SEA SPARROW/ESSM
DSU-34 TDD

Standard Missile
MK-45 TDD

Free-Fall Weapon Fuzes

FMU-139 A/B, Electronic Bomb Fuze

DSU-33B/B Proximity Sensor

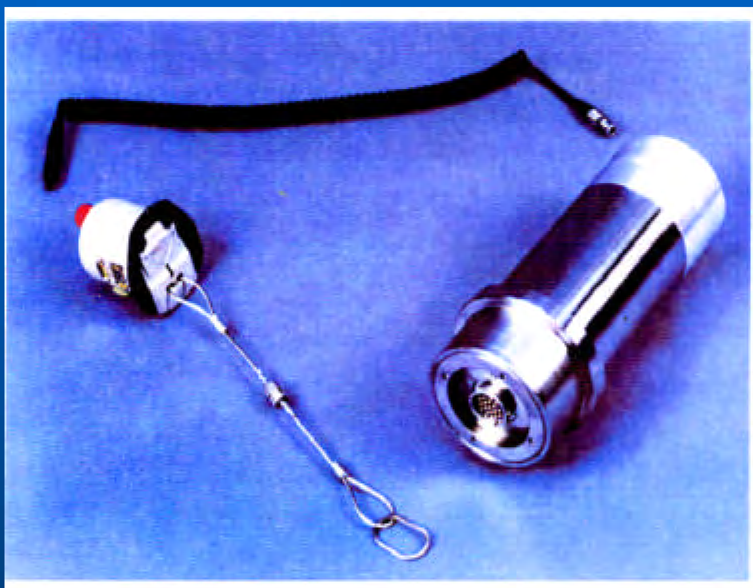
FMU-143, Electronic Bomb Fuze

FMU-140 /B, Dispenser Proximity Fuze

FMU-139 Rebooster Program

- FMU-139, joint in-service, general-purpose fuze
- The FMU-139B/B is a retrofit to the current FMU-139A/B fuzes
- Improvements include:
  - Replacement of CH-6 booster pellets with PBXN-7
  - The addition of two (2) transvoltage suppressors
  - Replacement of explosive leads with new leads
  - Elimination of the MK-3 Arming Wire
- Production startup January 2000
- 200,000 FMU-139B/B fuzes completed by the end of FY 01

Support for Joint Fuzes



FMU-159
Hard Target Smart Fuze

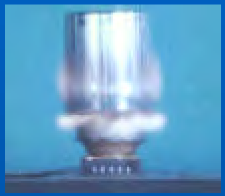
FMU-152
Joint Programmable Fuze (JPF)

Fuze Technology Programs

Low Energy EFI Technology

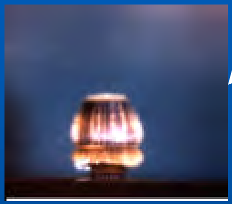
- State Of The Art
  - Low Energy Exploding Foil Initiators
  - Alternative Explosive Materials
  - Increase Energy Output
- Benefits
  - Significant Cost Savings to the Navy
  - Significant Performance Enhancements

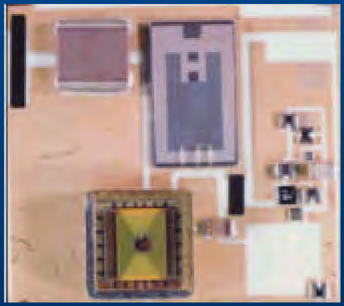
Low Energy EFI Detonator
- Fully Qualified
- Manufactured by Silicon Designs and Reynolds Systems



EFI Firing a Booster

Booster Detonating

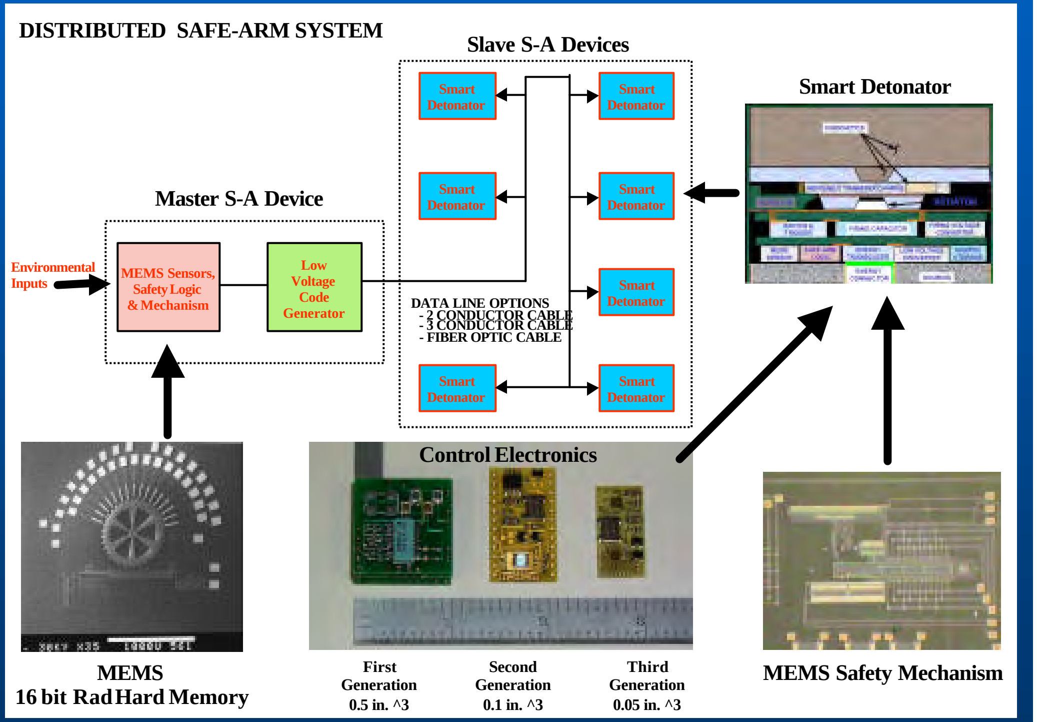




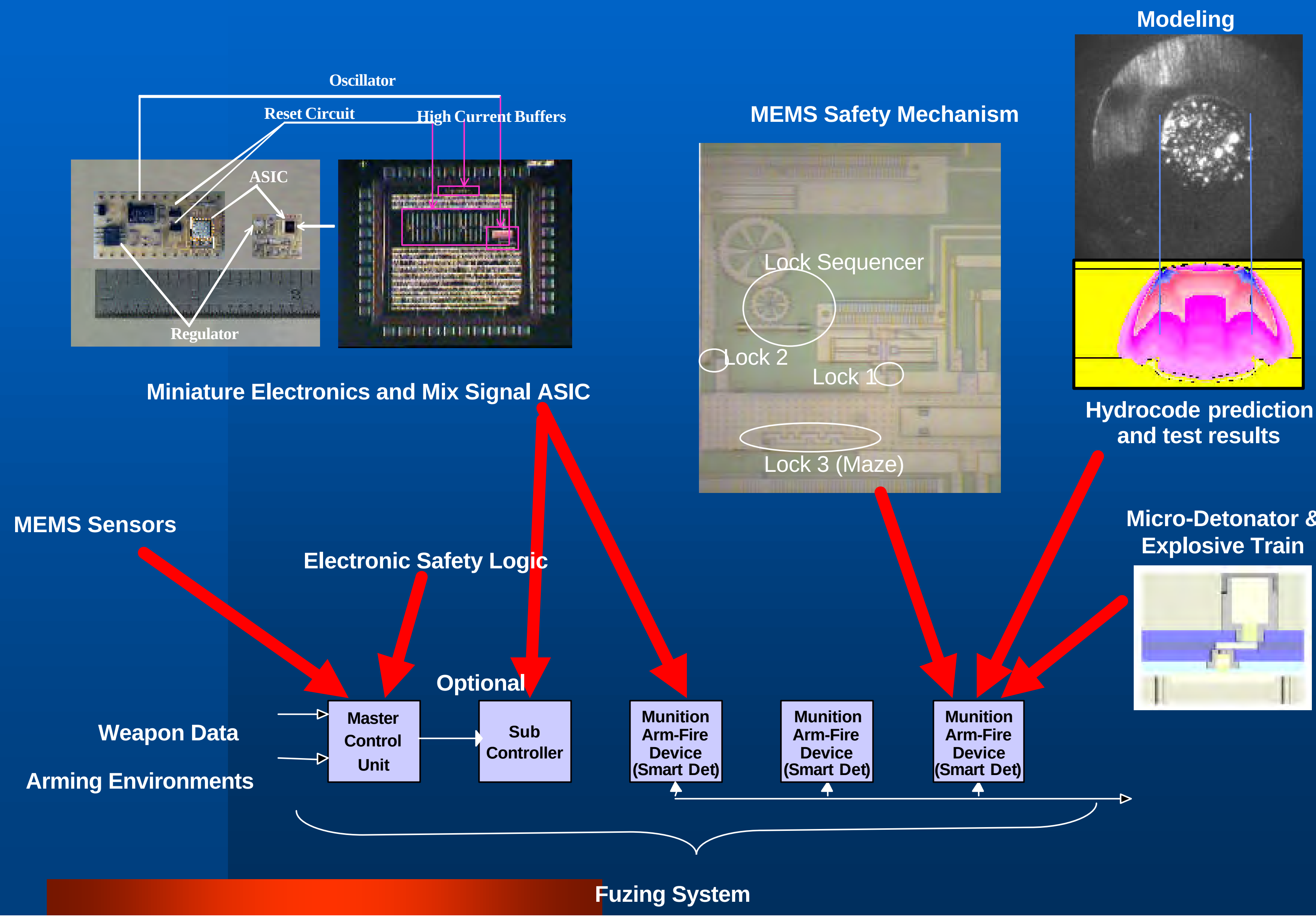
Integrated EFI with Solid State Fire Set

MEMS-Based Distributed S-A

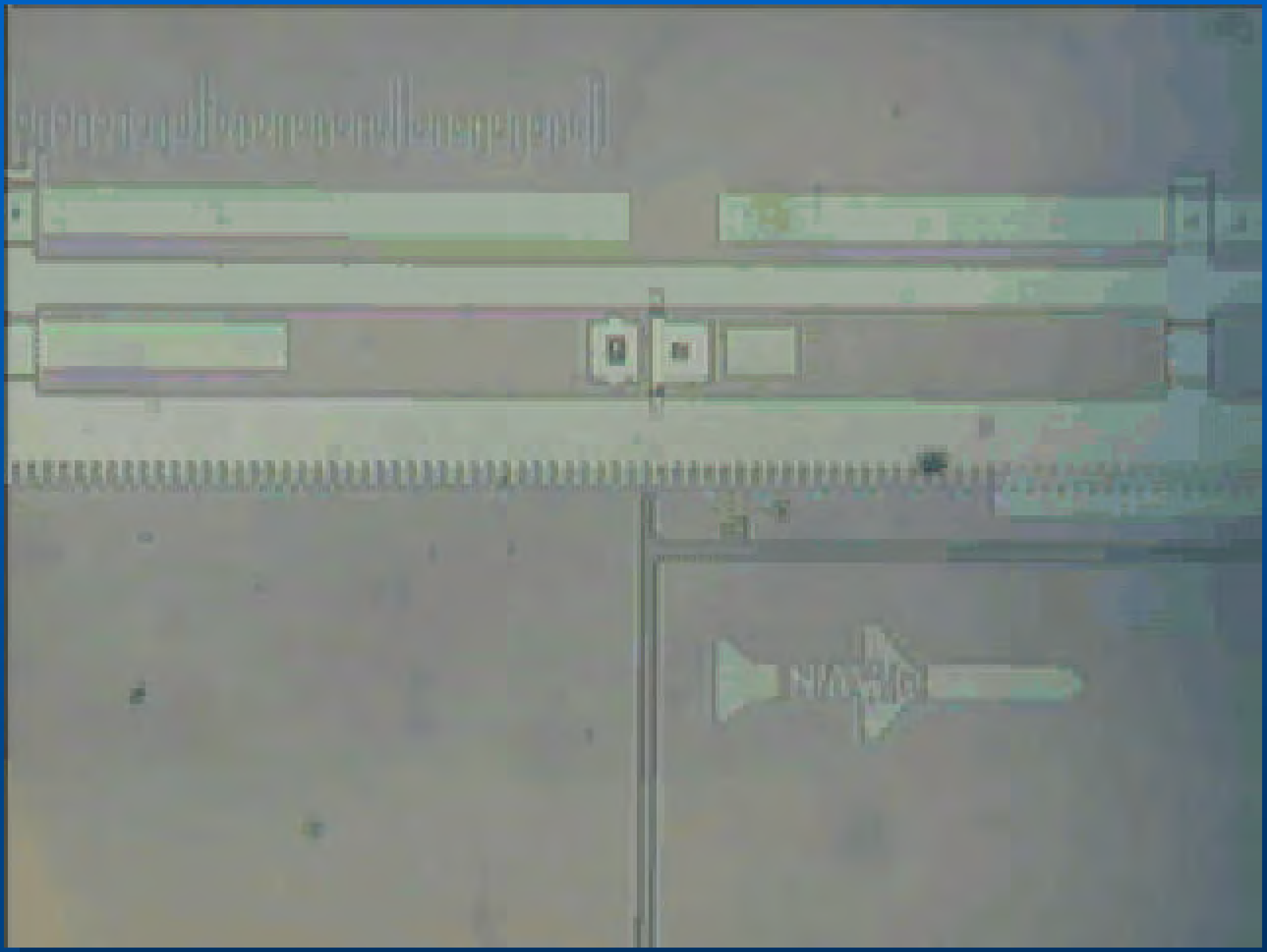
- **Description:**
  - Master control unit senses arming environments per MIL-STD-1316, then generates unique arming commands to selected "slave" detonators
  - Each det contains MEMS mechanical locks to prevent inadvertent arming
  - Up to "n" dets distributed within system to enhance performance
- **Major Accomplishments:**
  - Safety analysis of arming commands
  - Shown MEMS ability to move loads
  - Proven basic in-line, out-of-line safety
  - Shown transfer of small charges
  - Significant size reduction of electronics
- **Future Plans:**
  - Complete design
  - Demonstrate Feasibility
  - Integrate Electronics/MEMS/Explosives



Enabling Fuze Technology

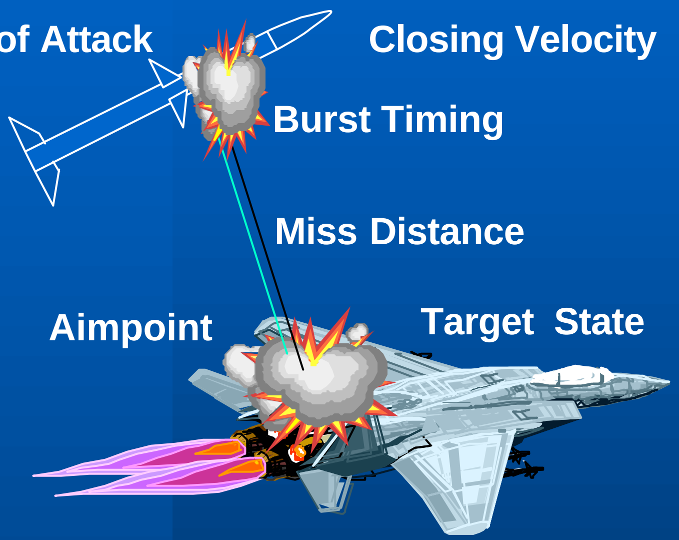


MEMS Based Distributed S-A (cont'd)



Computer controlled rack driver

Precision Intercept



What Are We Trying To Do

- Develop methods to produce missile management algorithms that maximize missile lethality
- Manage intercept conditions for optimal lethality using:
  - Target state information from missile sensors and network centric warfare grid
  - Missile endgame trajectory and attitude w.r.t. target orientation
  - Warhead mode options
  - Knowledge of target-warhead vulnerability space

What Makes it Possible

- High resolution forward-looking endgame sensors
  - Reduce measurements errors
  - Target extent and orientation information
- Taking advantage of synergies between warhead/target information and missile dynamics
- Modern processors can support higher processing loads

What Difference Will it Make

- Greater Pk over wider encounter conditions & spectrum of target types
- Offers reduced weapon size / weight by providing same lethality with smaller warhead

Short Pulse Laser TDD

- **Objective**
  - Provide High Endgame Lethality For SBD Against Sea Skimming Supersonic Maneuvering Targets In Benign and Adverse Environmental Conditions
  - Extend the Operational Capability of Fuzing Subsystems to Include:
    - All Aspect Encounter
    - Adverse Weather
    - Increased Target Sets
    - Low Altitude Severe Clutter Operation
  - Demonstrate operation in adverse weather to Support Warhead Lethal Range
  - Apply Advanced Sensor and Receiver Technology to Low Altitude SBD Problem

- **Approach**
  - First Order Analysis Shows Good "All Weather" Capability
    - Short Pulse Laser Sensor
      - Discriminates Against Aerosols and Clutter
      - Target Profiling
  - High Peak Power Narrow Pulse Laser Transmitters Offer:
    - Small Size and Volume
    - Large Target to Aerosol Backscatter Ratio
  - High Bandwidth / High Gain Receivers Offer:
    - Increased Signal to Noise Ratio
    - Increased BW & Sensitivity for Short Pulses

- **Payoff**
  - Increased Pk Against SBD Targets
    - Adverse Environmental Conditions
      - Aerosol
      - Sea Clutter
    - All Aspect Encounter

SEAD Fuze

Objectives:

- **Direct target detection design**
- **Establish low probability of false alarm in clutter with a high probability of target detection**
- **Fuze cost compatible with missile platform**

Approach:

- Exploit MMW target/clutter discriminants using radar (amplitude, phase, polarization, etc.) and radiometric data
- Mature the target/clutter discrimination technologies through analysis, simulation, and critical experiments with a measurement sensor.

Payoff:

- **Improved Pk through direct target measurements**
    - **Independent of Terminal Approach**

Lessons Learned:

- Strike TDD requirement driver is false alarm rate on clutter
- Target/clutter discrimination based on return amplitude alone is not reliable
- Target/clutter discrimination demonstrated with polarization, phase, and radiometric methods
- Phase processing is least expensive
- Radiometry is lowest risk

Summary

- Navy Lead for Missile and Free-Fall Weapons Fuzing

Supporting

➡ Technology

➡ Development

➡ Production

➡ In-Service

NDIA 45th Annual Fuze Conference

Ordnance Fuzing/Safety & Arming Programs Overview

Anh N. Duong

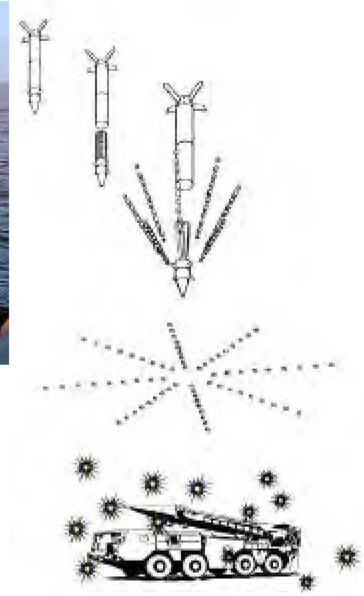
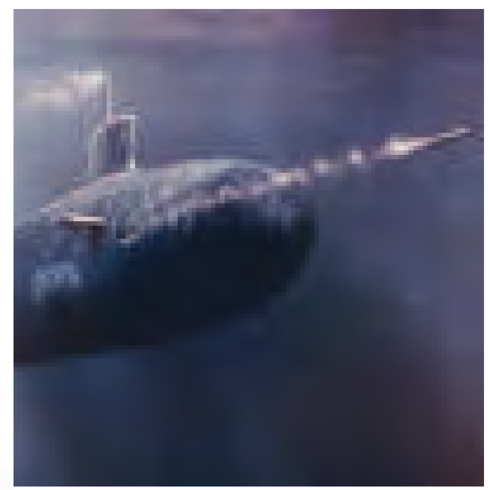
Explosives & Undersea Weapons Program Manager
NSWC - Indian Head

NAVSEA
INDIAN HEAD
Surface Warfare Center Division

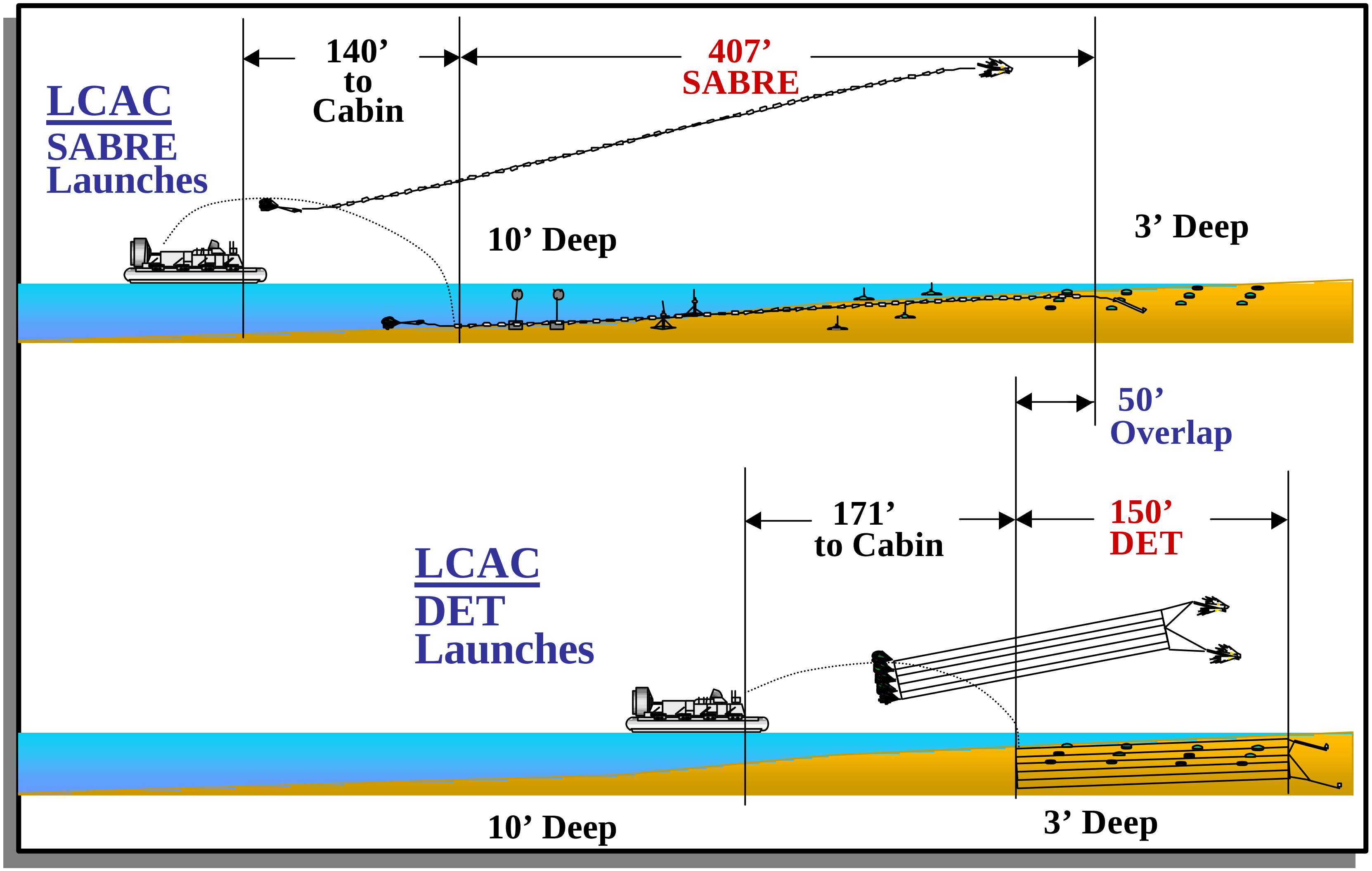
OUTLINE

- Current Development Programs
- Product Improvement Programs
- Applied MEMS Technology Programs



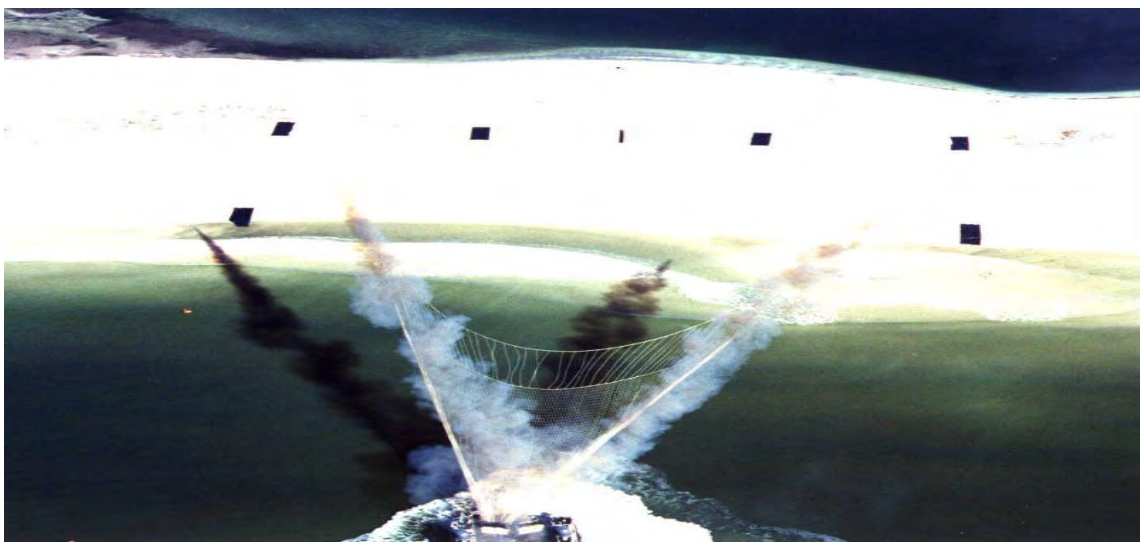
Current Development Programs
Navy Assault Breaching Systems

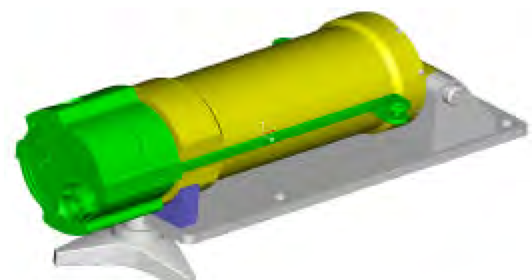


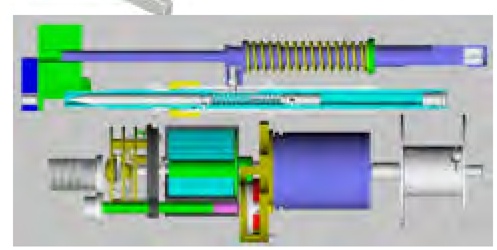
DET SURF ZONE MINE CLEARANCE SYSTEM TEST

DET Fuze/S&A

- ♦ **Distributed Explosive Technology (DET)**
  - **180’x180’ Explosive Net Used in Surf Zone Mine Clearance**
- ♦ **All Mechanical Fuze/Safety and Arming Device**
- ♦ **DET Technical Evaluation Completed**
- ♦ **DET Operational Evaluation Currently on Hold**
  - **May be Combined with SABRE OPEVAL Scheduled FY03**







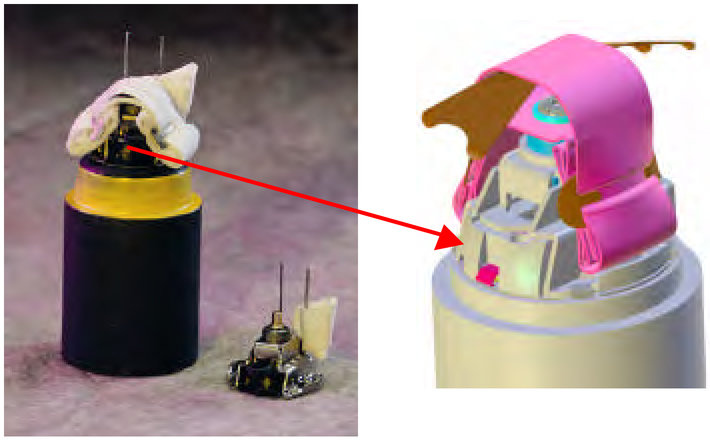
SABRE Fuze/S&A

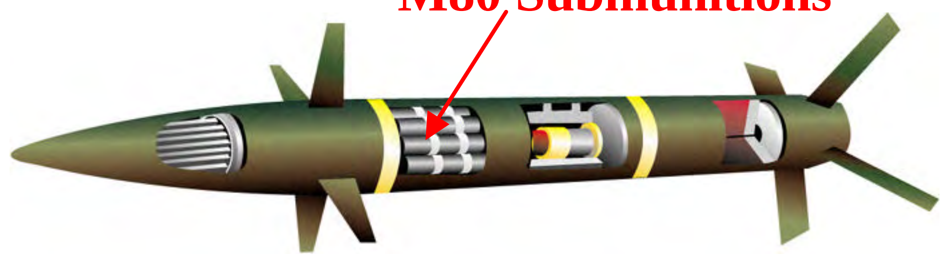
NEW START ***-- New Fuze/S&A for Shallow-water Assault Breaching (SABRE) System***

- **Contractor Development - Contract Award in Process**
- **Fire-and-Forget Fuze/Safety and Arming System**
- **Requires Extremely High Reliability**
- **Support SABRE System MS III Production Decision of March 2003**

P3I Programs

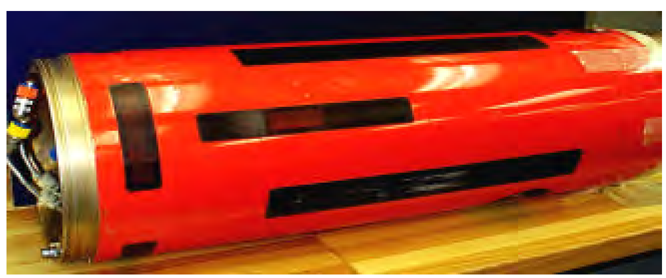
- **NSFS ERGM EX171 M80 Submunition PIP Proximity Fuze Insertion**





M80 Submunitions

- **Next Generation Small Active Electromagnetic Torpedo Fuze**

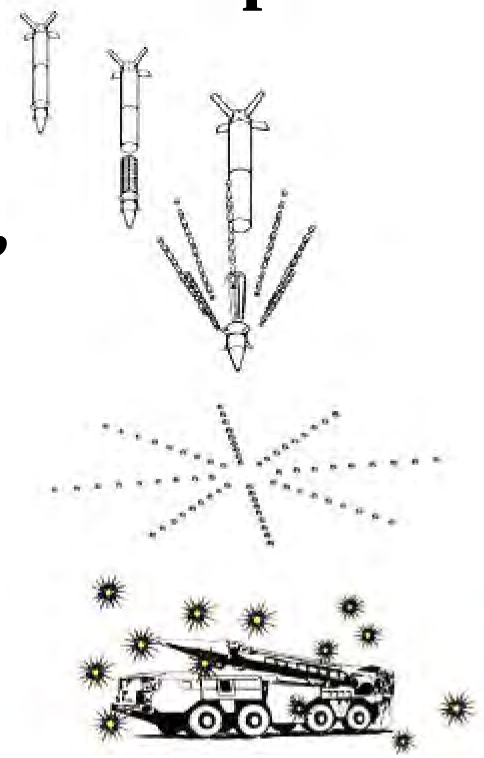


EM Fuzed Torpedo Shell Section

NSFS ERGM M80 Product Improvement Program (PIP)

PROGRAM GOALS:

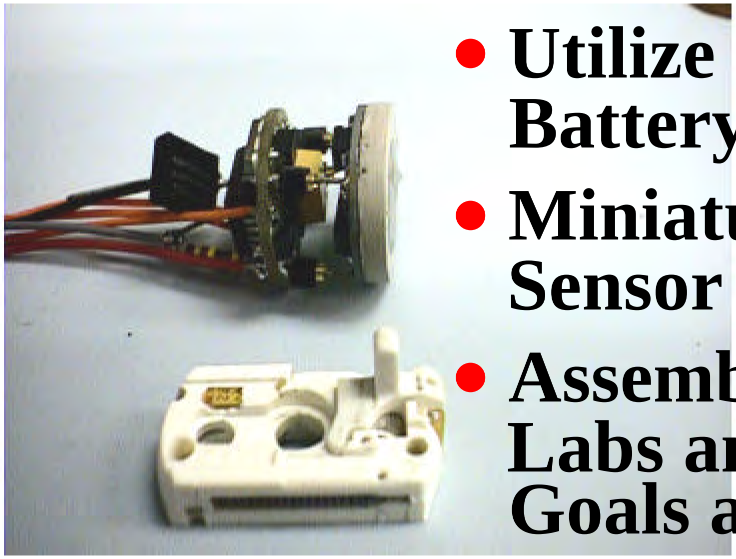
- ♦ **Develop an Add-on Proximity Fuze System**
  - **Inserted within the M234 SD Fuze Envelope**
  - **Minimal Impact to M234 SD Fuze High Rate Production Equipment**
  - **Meet ERGM Safety, Performance, Environmental, & Life Cycle Requirements**



NSFS ERGM M80 PIP
Proximity Fuze System Insertion

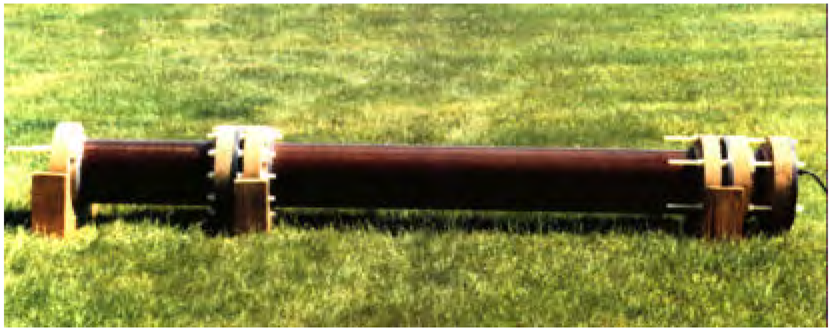
TECHNICAL APPROACH:

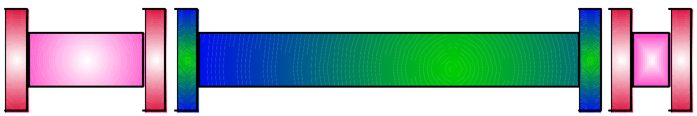
- One-for-One Replacement of the M234 Self-Destruct (SD) Fuze Slide Assembly



  - Utilize Gun Launch Environment for Battery Activation
  - Miniaturize the FM/CW RF Proximity Sensor of the M734A1 Mortar Fuze
  - Assemble Expertise from Army / Navy Labs and Industry to Achieve Technical Goals and Reduce Critical Risk Areas

Reduced Power Active EM Fuze Underwater Torpedo Applications



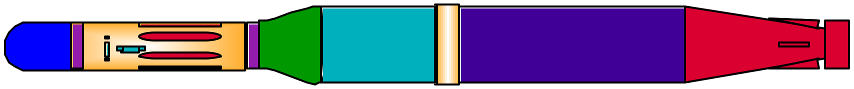


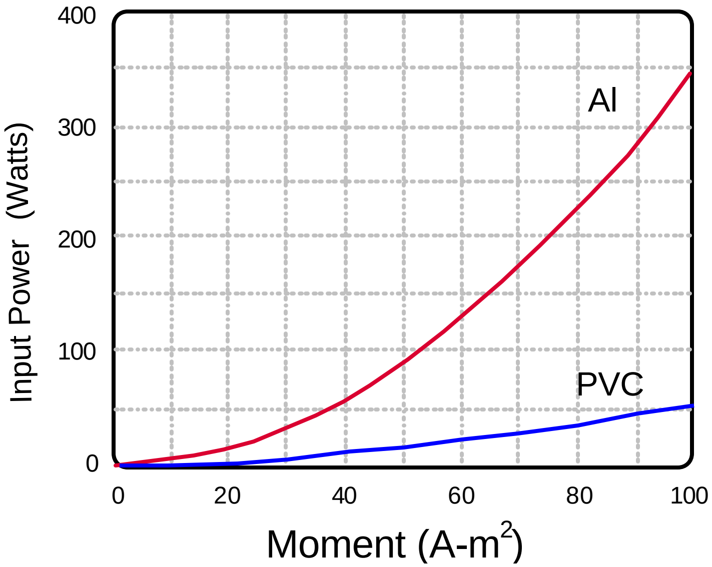
Proof-of-Principle Demonstrated

- **7:1** Reduction Input Power
- Multiple Transmitter Designs
- Suitability of EM Fuzing for Small Diameter torpedoes

Successful Torpedo Sea Run Tests

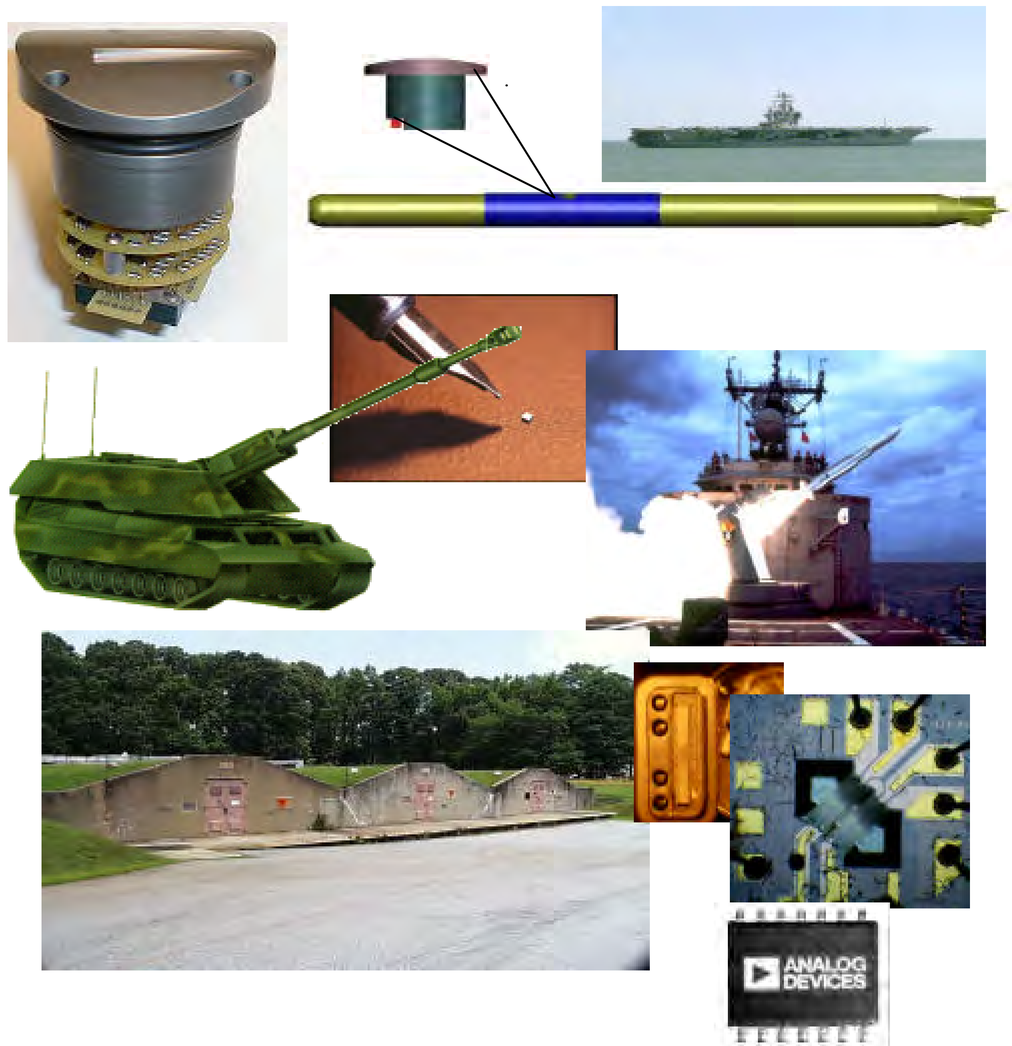
- Dynamic Environments
- Target Detection
- Model Validation





Applied MEMS Technology

- **Surface Ship ATT F/S&A Device**
- **Standard Missile Embedded Sensors**
- **Ordnance Inventory & Surveillance**



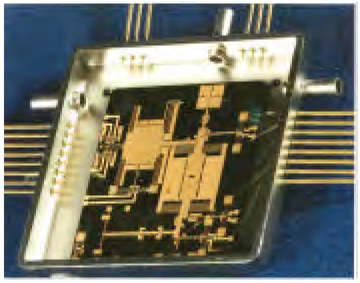
NAVY MEMS-BASED F/S&A PROGRAM

OBJECTIVE:

- **Apply & Transition MEMS Technology to Undersea Weapon F/S&A Systems**

APPROACH:

- **Capitalize on the MEMS Industrial Base**
  - **Commercial (COTS) Sensors & Devices**
- **Leverage DARPA Funded Infrastructure**
  - **Design, Modeling & Analyses Capability**

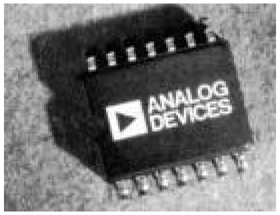


- **Demonstrate MEMS F/S&A Reliability**
  - **Assure Weapon Safety with Miniaturized Modular Architecture**

NAVSEA INDIAN HEAD Surface Warfare Center Division

MEMS F/S&A TECHNOLOGY
COTS / Modular Components

OFFICE OF NAVAL RESEARCH



Impact Sensor

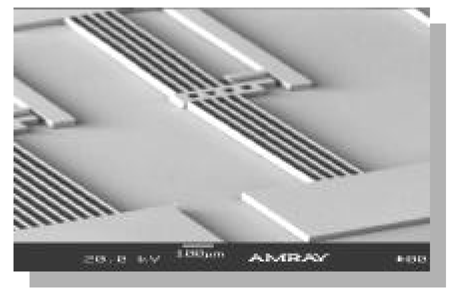
Flow Sensor: Pressure Differential

Inertial Measurement Rate Sensor

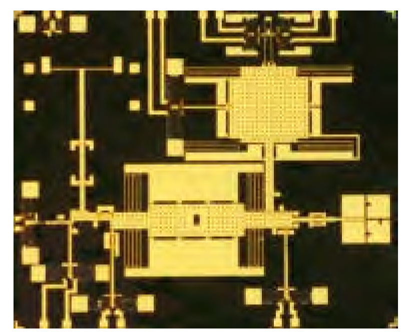
Typical Building Block Components for MEMS-Based Exploder

DARPA MTO MEMS

Initiation System
Slapper, Fire-set & Optical Charging Circuit



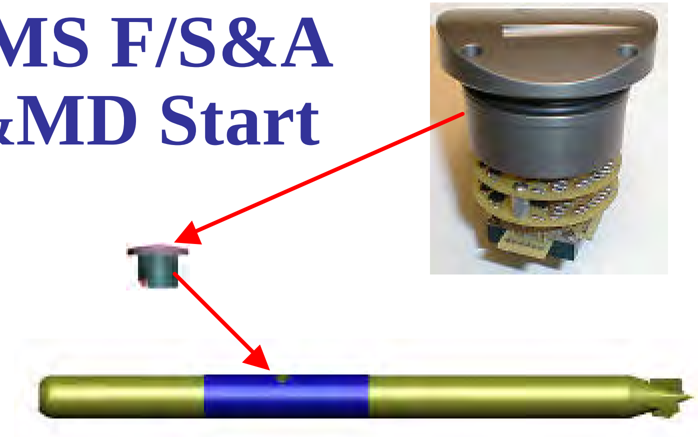
DRIE MEMS CHIP



LIGA S&A Chip

TORPEDO MEMS F/S&A

Main Objective: **Transition MEMS F/S&A Technology for FY 02 CCAT E&MD Start**



Technology Focus:

- **MEMS Fabrication**
- **Packaging Reliability and Robustness**
- **Inertial Sensor (IMU) Technology**
- **Remote Initiation Systems**
- **Optical Interruption**

Prototype Development:

- **Develop/Build 15 S&A Prototypes**
- **Conduct Environmental and Field T&E**
- **Utilize IHD MEMS Clean Room for MEMS S&A Prototypes Packaging, Assembly, & Test**

Standard Missile

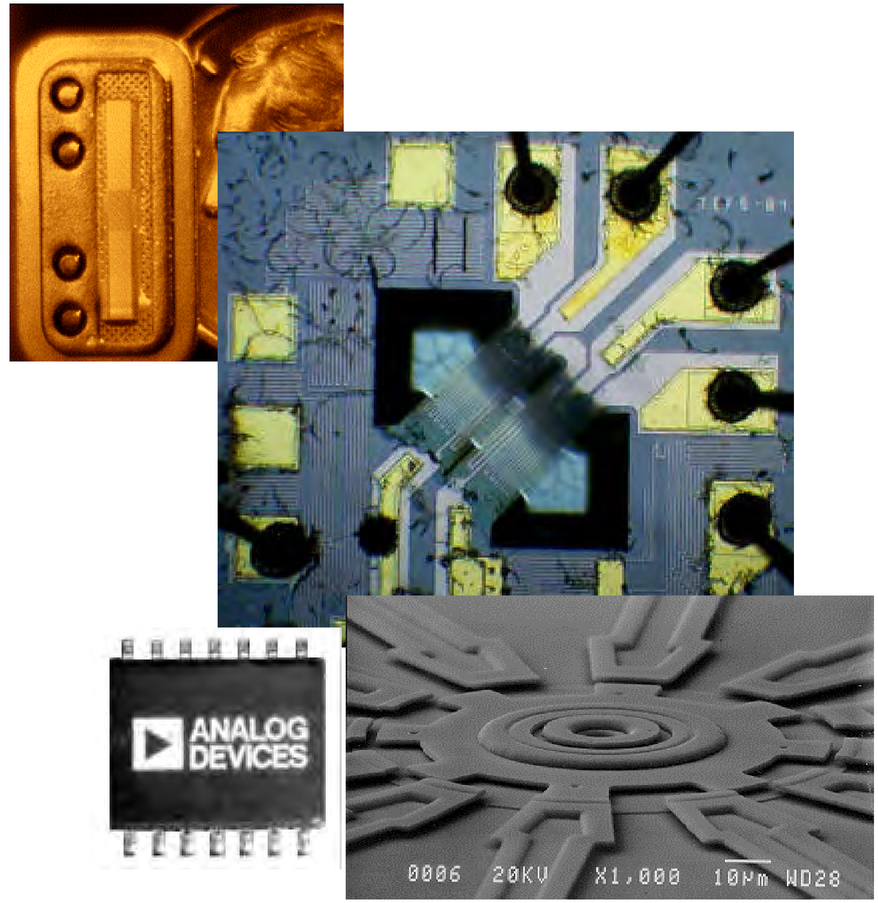
- Installing Temperature Data Loggers to Canisters
- Funded to Develop Embedded Stress Gauges
- Funded to Develop Embedded Ultrasonic Sensors

Advanced Technology Ordnance Surveillance (ATOS)

- Selected by OSD as an FY 01 Advanced Concept Technology Demonstration
- Demonstrate operational utility of miniature radio frequency identification (RFID) tags coupled with micro-electromechanical sensor (MEMs) technology for use in tracking/monitoring critical items:
  - Joint “high dollar/low density” munitions
  - Category I munitions (high potential of theft/terrorist use)
  - Future Potential: Medical and biological supplies, perishable substance and other environmentally sensitive commodities, DU munitions, etc.

MEMS Sensors

- Temperature
- Humidity
- Stress/Strain
- Acceleration
  - Shock/Vibration History
- Chemistry Lab on a Chip
  - Presence of Degradation Products
  - Stabilizer Depletion



FUZE / SAFE & ARMING FOR THE 21ST Century

- **Challenges / Opportunities**
  - Shrinking DOD budgets / downsizing
  - Affordable weapon systems / reduced LCC
  - Smarter, multipurpose weapon systems
  - Acquisition reform
  - Maintain critical smart F/S&A core within DOD
  - Miniaturization

- **Approach**
  - Focus on electronics & emerging MEMS technology in industry
  - Increase joint service collaborative efforts
  - Develop “building Block” approach for universal application

U.S. Army Materiel Command

COL(P) Vincent Boles

Deputy Chief of Staff for Ammunition

Ammunition Update to 45th NDIA Fuze Conference

17 April 2001

AMERICA'S ARSENAL FOR THE BRAVE

AMC-Army READINESS Command… Supporting Every Soldier Every Day

Spectrum of Military Operations
Strategic Nuclear War
Tactical Nuclear War
Limited Conventional Conflict
Insurgencies, Counter-insurgencies
Strikes
Raids
Counter Drug
Domestic Disaster Relief
Military to Military Contacts
Domestic Civil Support
Humanitarian Assistance
Show of Force
Invincible in War
Persuasive in Peace
Global Conventional War
Regional Conventional War
Peace Enforcement
Counter Terrorism
NEO
Peace Operations
Security Assistance
Pre-Crisis Access
Exercises
Environmental Operations
Arms Control
Soldiers on Point for the Nation

Topics

- ***Fuze Base Concerns***
- **Munitions FAA 2000**
- **Aging Stockpile**
- **Recapitalization**
- **Army Procurement**
- **Fuzes in Production / Procurement**
- **Thoughts I Want to Leave You With**
- **Thoughts to Take Away**

Fuze Base Concerns

- *In Oct '00, Initiated Study to Look at State of the Power Supply Base*
- *Industry Participated & Provided Valuable Input*
- *Formulating Strategy to Support this Part of Base Critical to Future Smart Munitions*
- *Recap will Place Burden for Reserve Batteries in Self-Destruct Fuzes*

Topics

- Fuze Base Concerns
- ***Munitions FAA 2000***
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- Thought to Take Away

Munitions FAA - 2000

- ✓ ***<u>Precision Munitions</u>*** ***- can reduce Army Logistics Footprint, but pace is too slow . . . Multiple Participants . . . T.T.P. 6300 Rounds***

- ✓ ***<u>Serious Issues in Fire Support</u>*** ***- cold war stockpile aging or declining, have delayed modernization***

- ✓ ***<u>Recapitalization Focus</u>*** ***- support for Low Cost Competent Munitions to bridge modernization gap, extend shelf life of stockpile***

- ✓ ***<u>Industrial Base</u>*** ***- Continue "commercialization" strategy to yield cost /process efficiencies with domestic/global competitiveness***

Topics

- Fuze Base Concerns
- Munitions FAA 2000
- ***Aging Stockpile***
- Recapitalization
- Army Procurement
- Fuzes in Production / Procurement
- Thoughts I Want to Leave You With
- Thoughts to Take Away

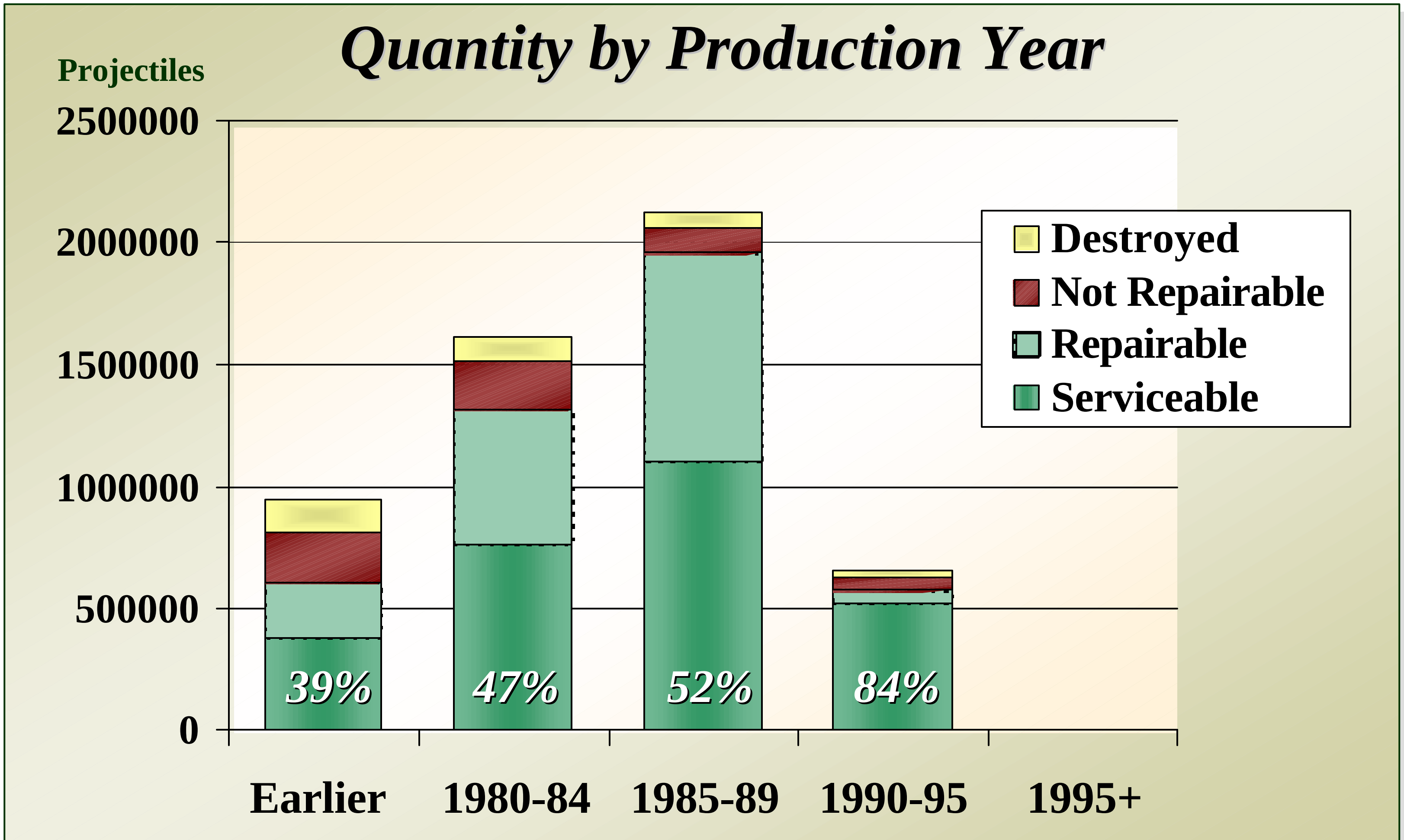
How Long Can We Rely on Aging Stockpile?

- ***Increasing signs of age in current stockpile - major suspensions in 60MM, Mechanical Time Fuzes, older 120MM tank ammunition***
- ***Decision to exclusively use SD-fuzed submunitions would require replacement/remanufacture of 4 M+ DPICM munitions and 100K MLRS -potential $22B bill***
- ***Over $100M in deferred maintenance on stockpile munitions - backlog growing - mainly substitute munitions***

Army is facing need to recapitalize conventional munitions stockpile within next 10 years

OR PUT ANOTHER WAY . . .

Aging Stockpile - 155MM DPICM



Projection for 2005

Topics

- Fuze Base Concerns
- Munitions FAA 2000
- Aging Stockpile
- ***Recapitalization***
- Army Procurement
- Fuzes in Production / Procurement
- Thoughts I Want to Leave You With
- Thoughts to Take Away

Recapitalization

- *Returns Ammo to "Zero Hours" Standard - Upgrade w/Technical Enhancements, Repairs, Shelf Life Extension*
- *Improve Existing Stockpile*
- *Technology Insertion (i.e. Self-destruct Fuze)*
- *Offset Demil Costs (Estimated Cost $78M)*

Recapitalization - - - Examples

- ***Self-Destruct Fuzes on M864 DPICM's***
- ***Convert M483's Into M864's w/Self-Destruct Fuzes***
- ***R&D $ for Low Cost Competent Munitions (LCCM) to Increase Effectiveness and Reduce Logistics Footprint***
- ***LCCM Fuze on DPICM***

Topics

- Fuze Base Concerns
- Munitions FAA 2000
- Aging Stockpile
- Recapitalization
- ***Army Procurement***
- Fuzes in Production / Procurement
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Near Term Procurement Ammunition, Army

Army Budget

($ in Millions)

APPROPRIATION	FY00	FY01
FAMILY HOUSING	1,142	1,188
MIL PERSONNEL	27,934	28,373
RDTE	5,245	6,298
MCA	1,573	1,300
OMA	26,946	23,827
PROCUREMENT	**9,443**	**11,005**
ERA		390
BRAC	144	280
CHEM DEMI	1,023	980
AWCF	62	
TOTAL*	**73,510**	**73,641**

**Totals may not add due to rounding*

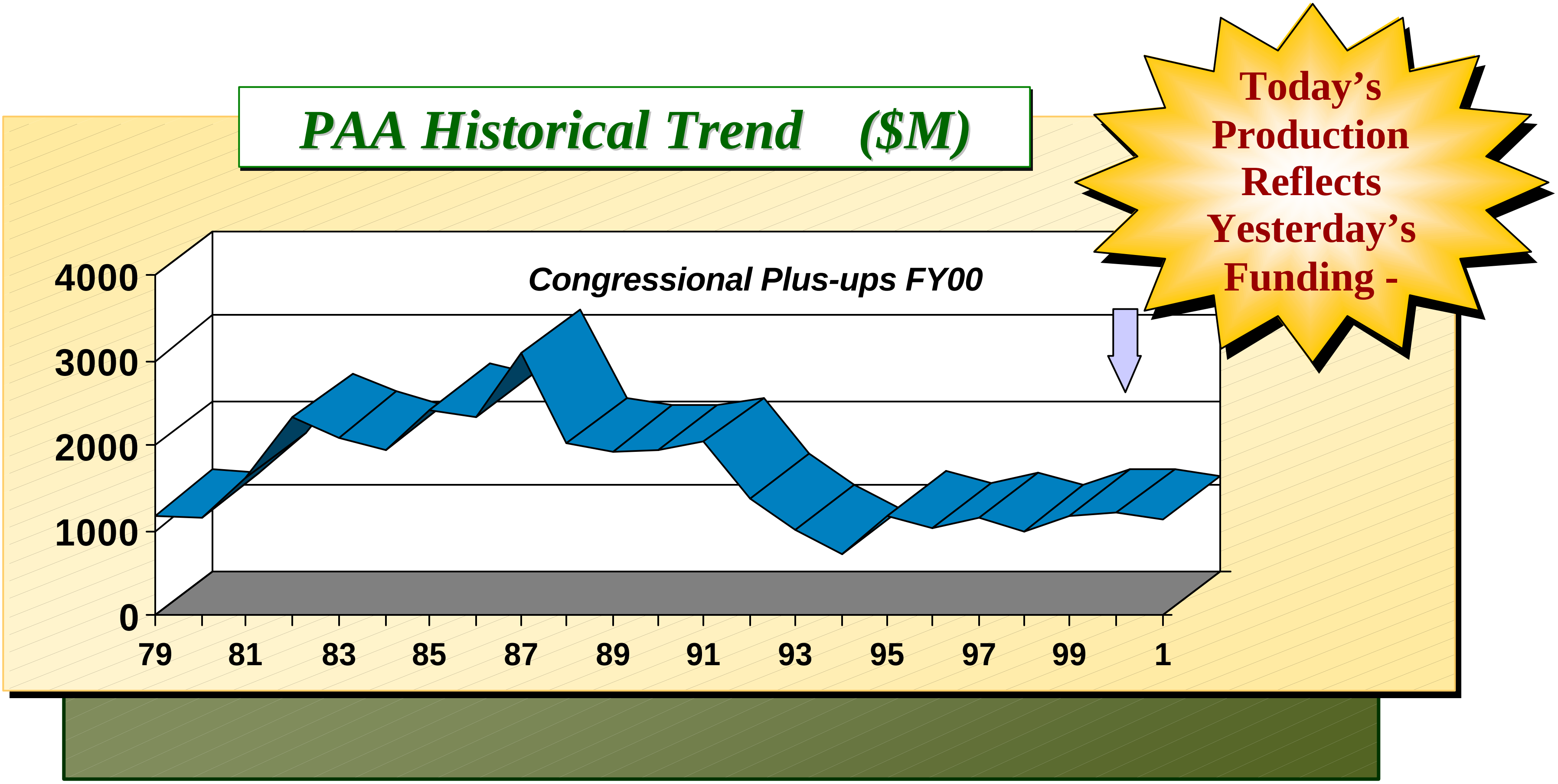
Procurement Appropriation

($ in Millions)

APPROPRIATION	FY00	FY01
AIRCRAFT	1,507	1,561
MISSILES	1,309	1,311
WTCV	1,712	2,455
AMMUNITION	**1,193**	**1,212**
OTHER PROCUREMENT	3,722	4,466
TOTAL	**9,443**	**11,005**

. . .OR PUT ANOTHER WAY . . .

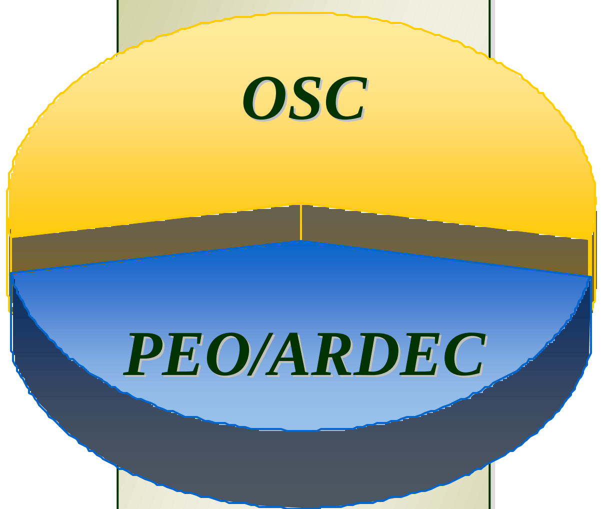
Near Term Procurement Ammunition, Army



Who Executes These Dollars

PAA

FY00



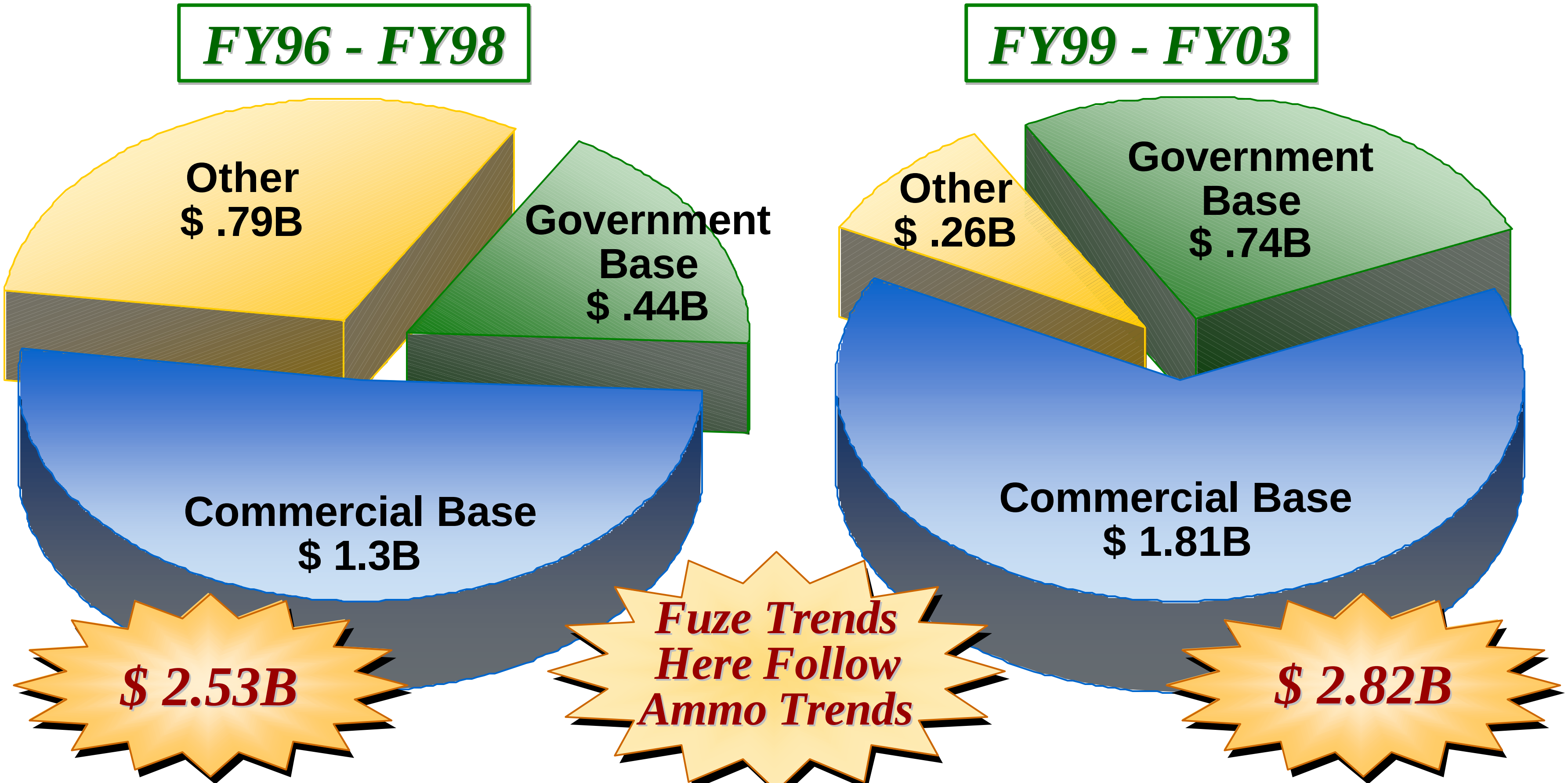
OSC	$631M
PM/ PEO/ARDEC	$500M

FY01

OSC	$626M
PM/ PEO/ARDEC	$536M

Where the Money Goes

GOCO vs COCO vs Other



Hardware Costs

AMC-Army READINESS Command... Supporting Every Soldier Every Day

Topics

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- ***Fuzes in Production / Procurement***
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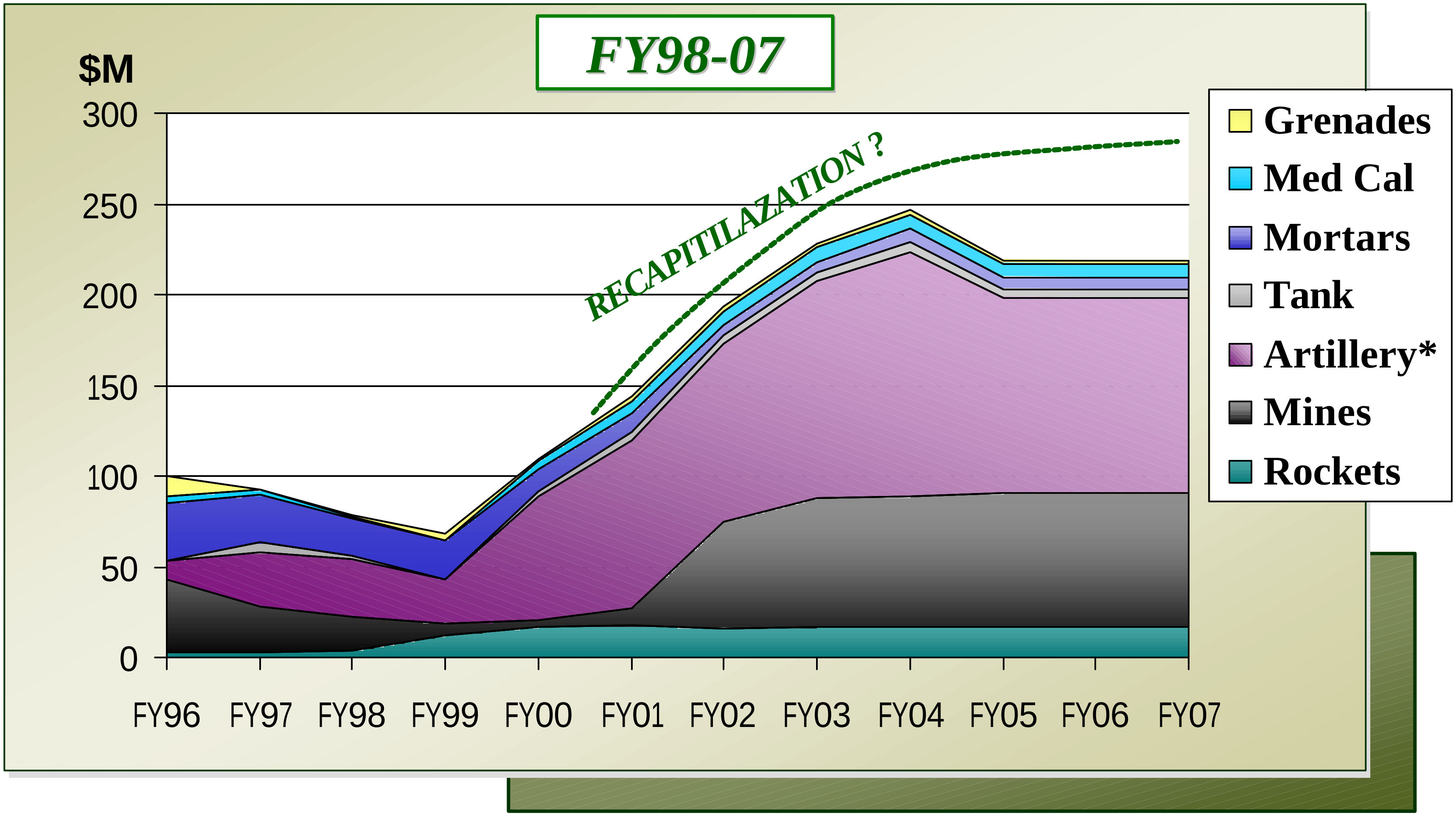
Fuzes In Production FY 02-03

- *M762A1 & M767A1 ET Fuzes for Artillery*
- *M782 Multi-Option Fuze for Artillery (MOFA)*
- *M734A1 Multi-Option Fuze for Mortars*
- *M776 MTSQ Fuze for 120mm Mortar*
- *M775 Mortar Practice Fuze*
- *M783 PD Fuze for Mortars - TC in June*
- *Grenade Fuzes - M213, M218, M228*

Fuze Procurement by Categories



Topics

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Thoughts I Want to Leave You With

Today :

- ✓ ***Recapitalization Impacts Program Priorities***

- ✓ ***Ammo Program Is Showing Positive Trends***
  - Costs Are Reduced
  - Improved Contracting Methods - Fixed Price, Multi-Year… Stabilizes Buys

- ✓ ***Fuze Production Trend Up***
  - Multi-year programs on M762A1/M767A1 and MOFA Fuzes

- ✓ ***Increase Fuze Tech Base Funding above the current level of $2M***

- ✓ ***Fuze Workshop at Picatinny on May 8, 9 & 10***

Topics

- **Fuze Base Concerns**
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- ***Thoughts to Take Away***

Thoughts to Take Away

- *The First Battle Is Logistics Readiness . . .*
  We Are Fighting It Now
- *Army Must Have a Logistics Overmatch (We Are the 9th Largest Army in the World)*
- *A Strong & Ready Army Requires a Partnership With A Strong & Ready Industry*

U.S. Army Materiel Command

COL(P) Vincent Boles

Deputy Chief of Staff for Ammunition

Ammunition Update to 45th NDIA Fuze Conference

17 April 2001

A Viewpoint from OSD

Anthony J. Melita

Deputy Director

Strategic and Tactical Systems, Munitions

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Outline

- DoD Organization
- Funding Trends
- SecDef Submunition Reliability Policy
- NATO STANAGs vice MIL-STDs
- Conclusions

DoD Organization

Secretary of Defense
Hon. Donald H. Rumsfeld

Deputy Secretary of Defense
Hon. Paul Wolfowitz

Under Secretary of Defense
(Acquisition, Technology & Logistics)
Mr. David R. Oliver, Jr., Acting
Principal Deputy
Mr. David R. Oliver, Jr.

Director, Defense Research and Engineering
Dr. Delores M. Etter, Acting

Director, Strategic & Tactical Systems
Dr. George Schneiter

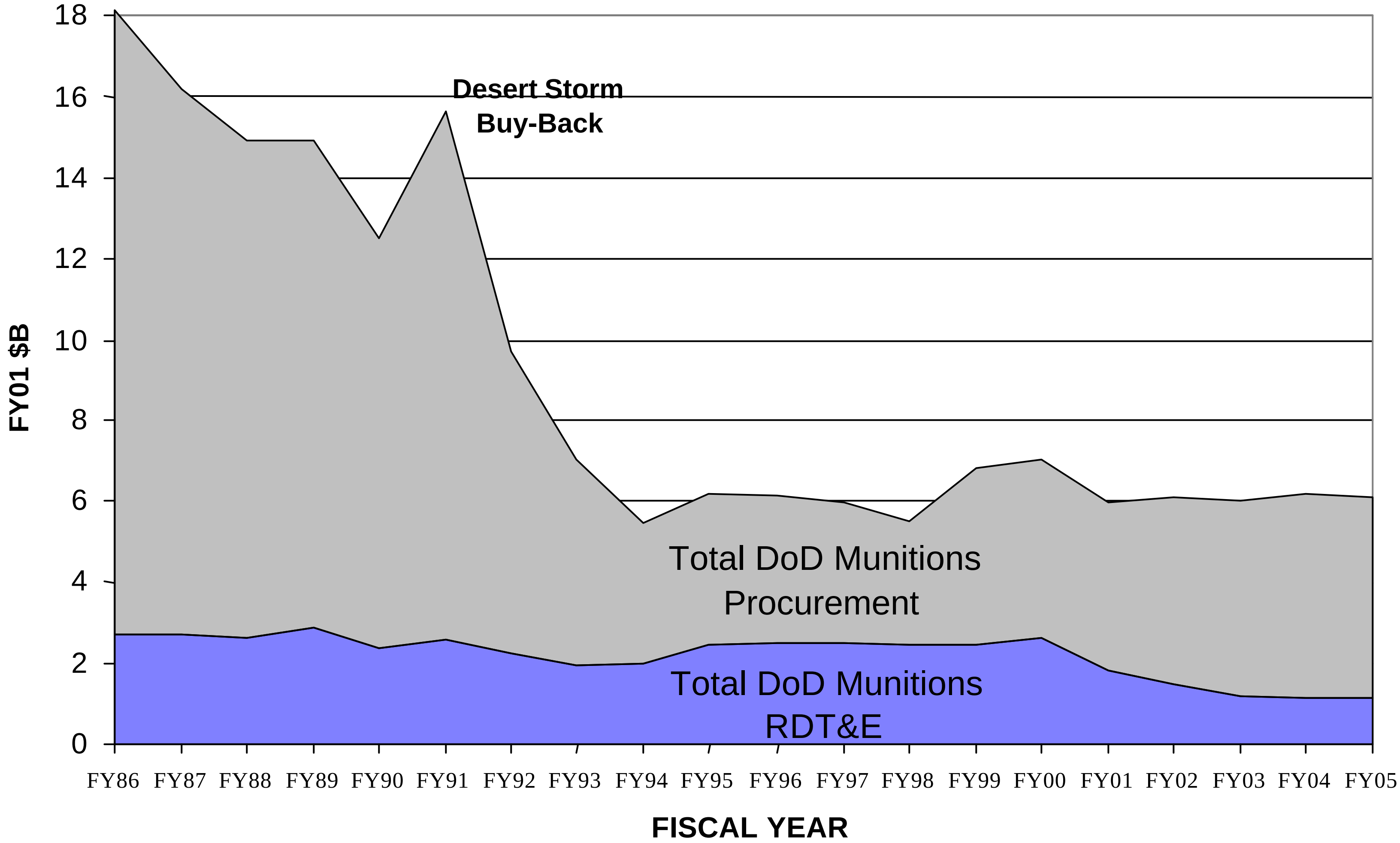
Deputy Dir., S&TS, Munitions
Mr. Anthony Melita

Secretary of the Army
Joseph W. Westphal, Acting

Secretary of the Navy
Robert Pirie, Acting

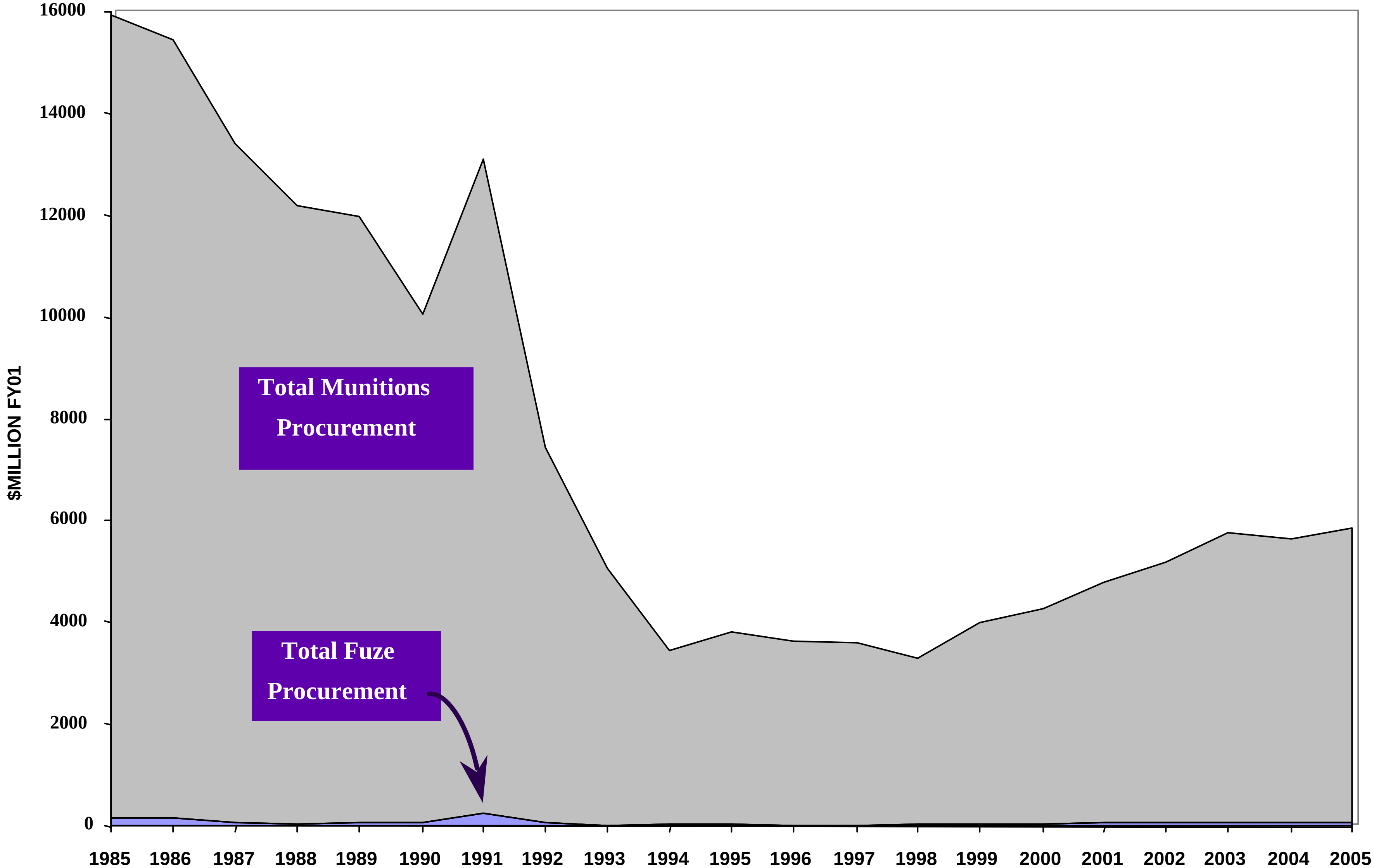
Secretary of the Air Force
Lawrence J. Delaney, Acting

DoD Munitions RDT&E and Procurement (Stacked Area)

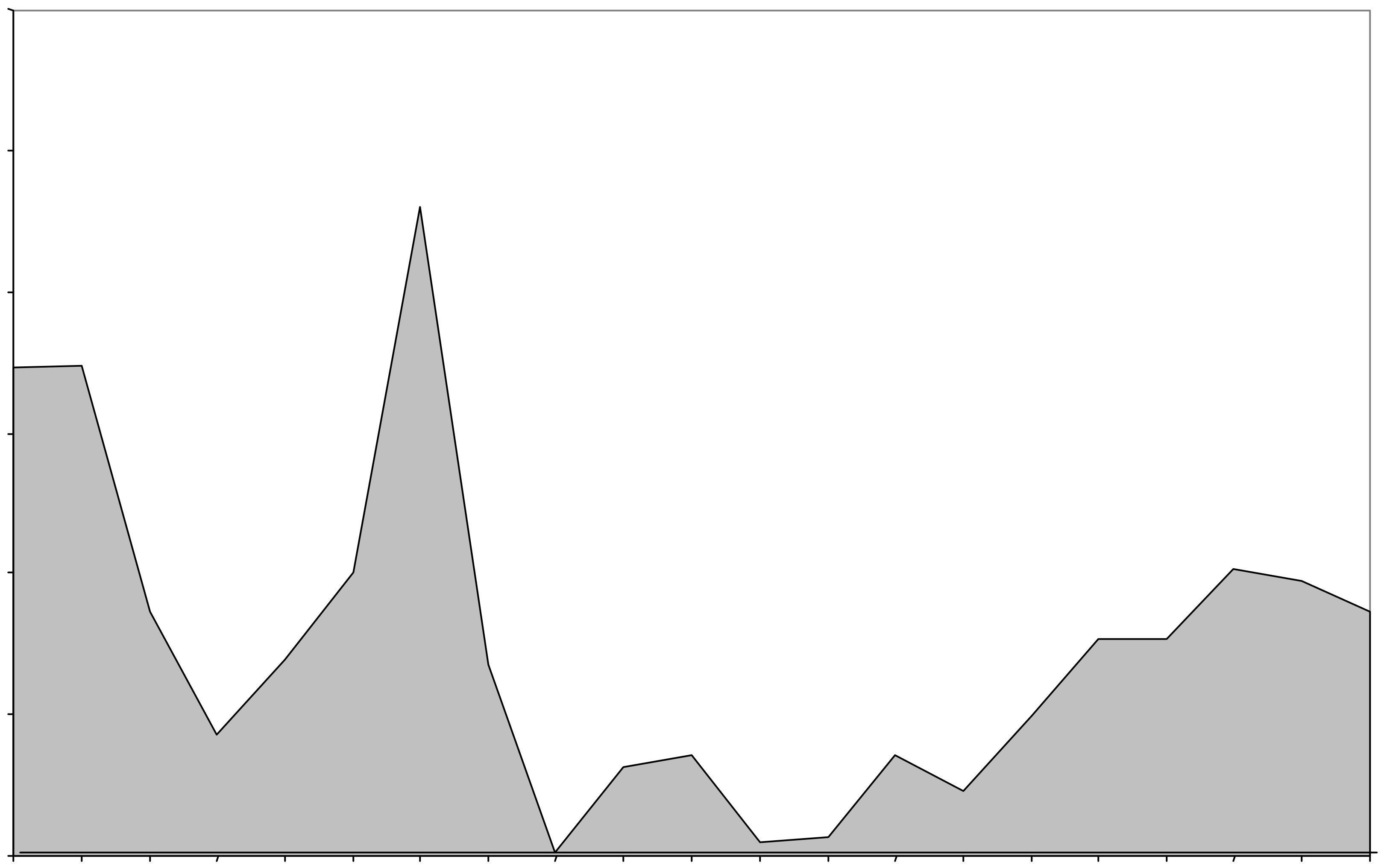


FISCAL TRENDS

Total Munitions and Fuze Procurement



TOTAL FUZE PROCUREMENT



SecDef Submunition Reliability Policy

Secretary Cohen, January 10, 2001:

Issue: Submunition weapons employed in Southwest Asia and Kosovo, and major theater war modeling, have revealed a significant unexploded ordnance (UXO) concern.

Policy: To reduce overall UXO through a process of improvement in submunition system reliability-the desire is to field future submunitions with a 99% or higher functioning rate. Submunition functioning rates may be lower under operational conditions due to environmental factors such as terrain and weather.

SecDef Submunition Reliability Policy

- Basis for new defense guidance
    - Increases combat effectiveness
    - Enhances safety of friendly forces during combat operations
    - Enhances safety of peacekeepers and civilians in post-conflict environments

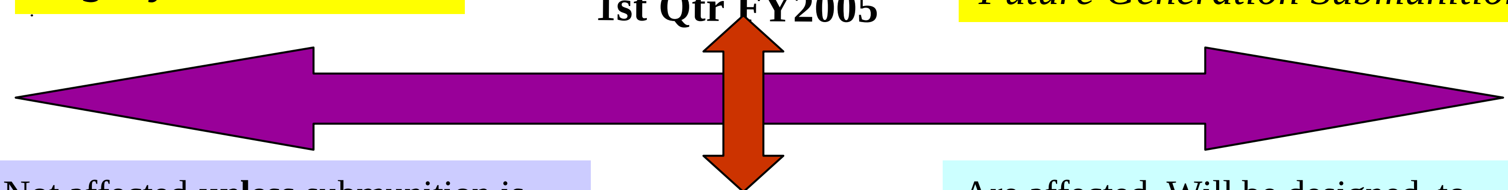
SecDef Submunition Reliability Policy

- *Timetable for replacement/improvement*
  - *Two Categories of Submunitions*
    - **Legacy - Active prior to 1st Qtr FY 2005**
    - **Future Generation - Milestone III after 1st Qtr FY 2005**

Legacy Submunitions

Future Generation Submunitions

1st Qtr FY2005



Not affected **unless** submunition is maintained in inventory and modified after 1st Qtr FY2005

Milestone III (Full Rate Production)

Are affected. Will be designed to meet 99%reliability functioning rate

SecDef Submunition Reliability Policy

Affected Weapons(Milestone III by 1QFY05 and beyond)

- •Extended Range Guided Munition (ERGM) - XM80 Submunition
- •155mm XM982 Projectile (Excalibur) - M80 Submunition
- •Guided-Multiple Launch Rocket System (G-MLRS) - M77 or M85 Submunition
- •2.75" HYDRA-70 Rocket - M73 Submunition
- •Joint Standoff Weapon (JSOW) - BLU-97 Submunition

SecDef Submunition Reliability Policy

•There is no intent to retrofit the existing submunition weapons inventory.

•Why a 99% reliability rate? - - because technology to achieve a 100% submunition functioning rate is not available at this time - - technology challenges remain both in the product development and manufacturing processes.

SecDef Submunition Reliability Policy

- USD(AT&L) will enforce of this policy for now.
- This policy guidance will be included in the next update of the DoD 5000 series.

NATO STANAGs vice MIL-STDs

USD(AT&L) , September 2000:

- Use internationally recognized commercial and/or NATO Standards
- Incorporate into munitions system acquisition programs
- Eliminate U.S. equivalents

Conclusion

- Fuze funding trends are bleak - Policy should have a positive effect
- Policy is to reduce overall UXO through a process of improvement in submunition system reliability-the desire is to field future submunitions with a 99% or higher functioning rate.
- Policy will be monitored by USD(AT&L) for now - will be included in the next update of the DoD 5000 series.